Metal Progress

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. . . . **Ernest E. Thum,** Editor

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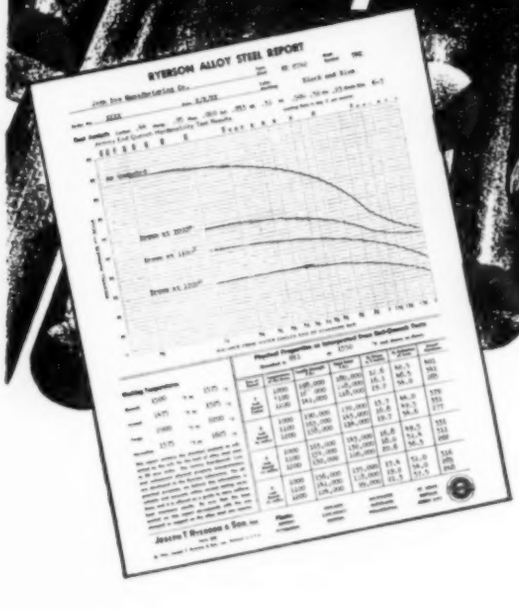

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Improved Treatments of Aluminum Alloys

By Max E. Tatman
Chief Metallurgist, Consolidated Vultee Aircraft Corp., San Diego, Calif.

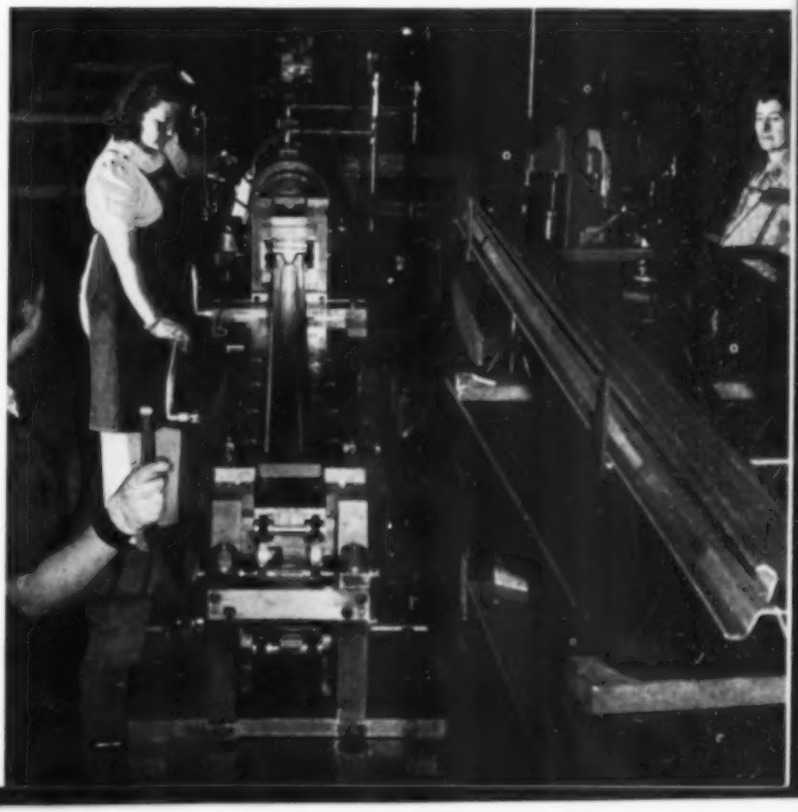
ALTHOUGH the most outstanding metallurgical advance, as far as the wartime aircraft industry is concerned, was the development of new high strength aluminum alloys which have been used to increase the strength-weight ratio of structural members in the newer aircraft, the improved equipment and technique for the heat treatment of the older aluminum alloys have also been a magnificent aid to the aircraft industry in meeting its heavy wartime production schedules. In these lecture notes (prepared as one of a series presented by the Los Angeles Chapter ASM last winter) the discussion will be confined to heat treatment, particularly of the 24S alloy — which is a representative of that family of alloys. Furthermore, since the greatest consumption of fabricated aluminum alloys consisted of wrought sheet, strip and plate, the writer will emphasize this type of material.

Warpage of Parts — In hardening the 24S aluminum alloy by heat treatment — which consists of heating at approximately 920° F. for 10 to 60 min. and then quenching in cold water — the primary objective of increasing the mechanical properties is attained, but not without a very undesirable secondary reaction, namely, warpage and distortion. This has been accepted as an unavoidable evil by airframe manufacturers who did not attempt to eliminate the cause but only the effect. This was accomplished through costly hand straightening or other re-forming operations. The various tools consisted of rubber mallets or hammers, rubber paddles, rawhide hammers, steel rollers, sand or shot bags, metal shrinkers and speed hammers. Since this corrective was time consuming we began to seek means of eliminating the cause of warpage and distortion when we really got into aircraft production, early in the war.

Since the warpage of any metal part during a quench is a function of the temperature differential between the metal immediately prior to quenching and the quenching medium, attempts have been made to reduce warpage by removing certain sensitive parts from the furnace or molten salt bath and allowing them to cool in air for several seconds before quenching. True, this diminished the amount of distortion; however, the mechanical properties and corrosion resistance were also reduced. In other schemes warpage has been reduced by quenching the hot metal with water fogs and sprays, but it was again found that mechanical properties and corrosion resistance suffered unless large quantities of water were used.

Recently there has been a trend in heat treating practice on the West Coast, especially on long narrow parts, toward quenching parts while in a

Fig. 1 — Production Set-Up for Stretching Roll-Formed Sections of Strong Aluminum Alloys After Quenching. This is a combination straightening and strengthening operation



vertical position. This practice does reduce the warpage and should be used whenever practicable. However, it is by no means a new development since it has been good practice in the hardening of broaches and drills for many years.

Stretching to Straighten

It is often possible to remove the distortion and warpage of sheet stock, roll-formed sections, extrusions, and other shapes of uniform cross-section, by stretching or rolling. Sheet stock is flattened at the aluminum alloy producer's plant by stretcher-leveling or by rolling. Extrusions, in general, are straightened after heat treatment by stretching sufficiently to remove all distortion.

Some aircraft companies use roll-formed sections in place of extrusions for wing and fuselage stiffeners. (Such material is usually roll-formed in the annealed condition and then heat treated in 12 to 20-ft. lengths.) It was well known that metals generally are hardened and strengthened by cold work (stretching) and some accurate studies on its effect on various strong alloys of aluminum had been made in 1937 by various members of the research laboratory of Aluminum Co. of America and independently by Roy A. Miller, chief structures engineer of Consolidated Aircraft Corp. Work at Consolidated was directed primarily toward the development of shop procedures in stretching, compression, and heat treatment schedules that would reliably produce airframe parts of enhanced properties. In the course of this work we found that considerably higher design values could be used, particularly in compression, if the roll-formed sections were stretched 3½ to 4% permanent set at the time of straightening. (These metallurgical developments were described at length by Kenneth R. Jackman, chief test engineer of Consolidated Vultee Aircraft Corp., in *Metal Progress* for July 1941.) The cost of controlling the stretch to 3½% set was practically nil since the sections, of necessity, had to be stretched at least ½% to straighten. This practice was first used in production on the four-engined B-24 in 1940; although, in 1938, it was used experimentally on Consolidated Model No. 31.

Figure 1 shows a typical production set-up for stretching roll-formed sections. The operator in left background is controlling the amount of stretch-under-load so that the permanent set will be 3½ to 4%. Immediately following the stretching operation, the stretched sections are tested for hardness by the operator in right background to insure that no annealed material has been included with parts supposedly quenched.

Rolled Blanks for Hydropress

In order to eliminate the necessity of reworking parts that usually are formed in the annealed condition and subsequently solution heat treated, many aircraft companies have recently adopted the practice of forming as-quenched material wherever possible. Hydropress and drop hammer blanks in thicknesses below 0.072 in. ordinarily cannot be heat treated without excessive warpage. Within the past few years several companies have found that it was possible to roll hydropress blanks of almost any shape (and in the annealed or soft condition) into coils 6 to 8 in. in diameter

Fig. 2 — Rack Load of Aluminum Parts Ready for Elevator-Type Heating Furnace, at Left. Note coiled hydropress blanks, and the long parts hung vertically

Table I — **Tensile Properties of Alclad 24S After Stretching and Aging (Two Months' Records)**

	24S-T80	24S-T81	24S-T84	24S-T86
Ultimate, max.	71,200	73,500	75,600	78,400
min.	66,000	67,250	72,500	74,200
Yield, max.	57,200	67,700	73,500	74,800
min.	52,200	61,500	67,000	69,100
Elongation, max.	13.0 *(a)*	8.0	7.7	7.0
min.	8.0	4.9	5.0	5.3

(a) Neglecting one value of 14.4%.

and then solution heat treat and quench the coils with little or no distortion. After quenching the coils are simply unrolled and placed on the hydropress form block for the forming operation. Figure 2 shows several coiled hydropress blanks ready for heating. It should also be noted that the long belt-frame sections at the right are hung in as nearly a vertical position as possible for the heating and quenching operations.

Mechanical Properties

Solution heat treatment of aluminum alloys is primarily for increasing the mechanical properties. In order to obtain consistent results the following variables must be closely controlled: (1) Solution temperature, (2) time at temperature, (3) time lapse between furnace and quenching medium and (4) cooling velocity. The importance of these variables has been frequently pointed out; however, it is desirable to re-emphasize the effect of these variables on the mechanical properties of alclad 24S.

If the heating temperature is too low, the hardening constituents in the alloy are not completely dissolved in solid solution in the aluminum and the mechanical properties will then be low even if all the other variables were properly controlled. On the other hand, if the temperature is too high, the eutectic temperature may be exceeded and then incipient melting will ruin the metal and it must be scrapped.

Soaking clad 24S parts for too short a time, even at the proper temperature, will as a rule result in the incomplete solution of the copper-aluminum hardening compound and the mechanical properties will be low. Ten minutes for thin material and 20 min. for thick material is sufficient; however, ordinarily a factor of safety of approximately 10 min. is added to each of the above soaking periods. Soaking times in excess of the minimum do not affect the mechanical properties of clad 24S; nevertheless, in order to minimize copper diffusion into the pure aluminum cladding, the soaking time should be very close to that specified.

Mechanical properties in excess of minimum specification values (which are always "commercial" and on the safe side) can be attained providing the lapse of time between the heat treating furnace and the quenching medium is short. Of course the thickness of the material does affect this safe interval — thin material should be allowed to cool no more than 7 to 10 sec. in the air during transfer, while thick material will be satisfactory even if exposed as much as 15 to 20 sec. Too long exposure to the air prior to the quenching operation reduces the yield strength as well as the corrosion resistance.

The cooling velocity during the quenching of 24S material is extremely important. Slow cooling, such as air cooling, usually results in

Fig. 3 — Probability Curve for Principal Strength Properties of Aluminum Alloy 24S (4.6% Cu, 0.6% Mn, 1.5% Mg) in Four Different Conditions

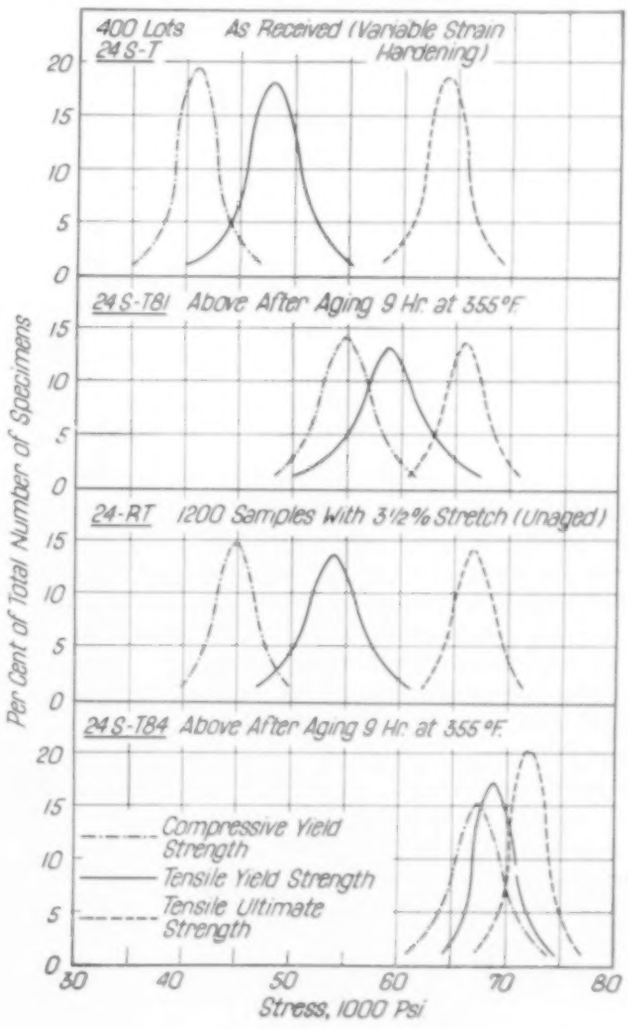


Table II — Approved Design Values

The data shown in this table apply to material procured to Specification AN-A-13. The data shown under the "0.063 and less" columns also apply to material of all thicknesses procured to Specification QQ-A-362.

Clad 24 S-O, Heat Treated at 930° F.

Mechanical Properties *(a)*	Strain Hardened by Stretching to 4.0% Set: 24R-T		No Strain Hardening: 24S-T		Variable Strain Hardening: 24S-T (As Received)		Strain Hardened by Rolling; 5.5% Reduction: 24S-RT (As Received)	
	0.063 and Less	0.064 and Over	0.063 and Less	0.064 and Over	0.063 and Less	0.064 and Over	0.063 and Less	0.064 and Over
F_{tu}	63,000	65,000	56,000	60,000	61,000	64,000	66,000	68,000
F_{ty}	50,000	52,000	37,000	38,000	41,000	42,000	51,000	53,000
F_{cy}	42,000	44,000	37,000	38,000	41,000	42,000	51,000	53,000
Elong.	10	10	11	11	11	11	8	8
F_{su}	40,000	41,000	34,000	36,000	37,000	38,000	40,000	41,000
F_{br} 1.5D	99,000	102,000	84,000	90,000	91,000	96,000	99,000	102,000
F_{br} 2D	125,000	129,000	106,000	114,000	116,000	122,000	125,000	129,000

All Varieties Aged at 375° F. ± 5° for 6.5 Hr. ± 0.25 Hr.

Mechanical Properties *(a)*	24S-T84		24S-T80		24S-T81		24S-T86	
	0.063 and Less	0.064 and Over	0.063 and Less	0.064 and Over	0.063 and Less	0.064 and Over	0.063 and Less	0.064 and Over
F_{tu}	67,000	70,000	60,000	62,000	64,000	67,000	70,000	72,000
F_{ty}	63,000	66,000	47,000	49,000	57,000	59,000	66,000	69,000
F_{cy}	64,000	66,000	47,000	49,000	57,000	59,000	66,000	69,000
Elong.	5	5	8	8	5	5	4	4
F_{su}	42,000	43,000	39,000	41,000	40,000	41,000	42,000	43,000
F_{br} 1.5D	100,000	105,000	90,000	93,000	96,000	100,000	102,000	106,000
F_{br} 2D	127,000	133,000	114,000	118,000	122,000	127,000	129,000	135,000

(a) F_{tu} is ultimate tensile strength; F_{ty} is yield strength in tension; F_{cy} is yield strength in compression; F_{su} is ultimate shear strength; F_{br} 1.5D and F_{br} 2D are the respective ultimate strengths in bearing at 1.5 and 2 times the hole diameter edge distance (centerline of rivet hole to edge of sheet in a lap joint).

mechanical properties far below specification minima. Fog quenching ordinarily does not result in a cooling velocity sufficiently rapid to prevent some intergranular precipitation during cooling; however, the mechanical properties approach the minimum specification values. Precipitation at the grain boundaries during cooling, nevertheless, reduces corrosion resistance of the material; for that reason fog quenching of parts for Navy seaplanes is prohibited.

Spray quenching of 24S material is satisfactory providing, of course, sufficient water is used to cool the material rapidly. Otherwise cooling conditions very similar to those described for fog quenching are the result.

Some statistical data on metal with solution heat treatment only, and the same after artificial aging are shown in Fig. 3, representative probability curves of clad 24S. The upper two sets of curves are for approximately 400 lots of "as-received" material, 24S-T unaged, and 24S-T81 artificially aged, respectively. The two lower curves apply to about 1200 samples of unaged 24-RT (3½% stretch) and the same artificially aged (24S-T84). The aging cycle used on these materials consisted of 9 hr. at 355± 5° F. (Incidentally, this aging cycle slightly underaged both the 3½% stretched material and the "as-received" sheet material.) It should be noted that artificial aging increased all the strength properties; however, the most marked increase was in the compressive yield strength.

Tests are constantly made on tensile coupons and used for production control of aged tempers of 24S, namely 24S-T80, 24S-T81, 24S-T84, and 24S-T86. Results of the precipitation heat treatment are segregated by shift and are quite uniform. Representative figures for a two-month period are shown in Table I and are consistently above design minima of Table II. The aging cycle used for all

(Continued at bottom of page at right)

Table III — Mechanical Properties of New Aluminum Alloys

Material		Tension: Yield	Tension: Ultimate	Tension: Elongation	Compression Yield
Clad R301-T	Typical	60,000	68,000	10.0%	59,000
	Minimum	57,000	64,000	8.0%	
Clad R303-T275	Typical	68,000	74,000	9.0%	70,000
	Minimum	64,000	70,000	7.0%	
Clad 75S-T	Typical	68,000	77,000	12.0%	70,000
	Minimum	64,000	74,000	8.0%	

Two Million Volt X-Ray Inspection Equipment

By David Goodman
General Electric X-Ray Corp., Chicago

READERS of *Metal Progress* will have noted, through the years, a series of articles recounting the development of X-ray equipment of greater and greater voltage, and their metallurgical uses on thicker and thicker pieces of metal, culminating in the description of the portable one million volt apparatus perfected in 1941 by General Electric X-Ray Corp. and the laboratories of its parent company. Now that the war is over it is permissible to describe a far more potent inspection tool, a "super-voltage" X-ray of two million volts, and the way it was used for inspecting loaded shells and bombs at the huge Elwood Ordnance Plant in northern Illinois. While the unit at Elwood was used primarily to examine the chemical charge of shells and bombs, its installation may serve as a pattern for the use of similar equipment in metal processing plants because of the manner in which the problems of protection, processing and production control were solved.

The importance of this equipment in government ordnance production can be seen from the fact that instead of hit-or-miss destructive testing, in which hundreds of shells are rejected if a major defect is found in one unit of a sub-lot, a plant can make non-destructive tests showing flaws at any depth or thickness in heavy parts. The speed of such high-voltage X-ray permits the examination of each piece in a suspect sub-lot. It also allows re-working of defectives and then X-raying them again to determine whether the flaw has been remedied. Experience at Elwood proved that when all factors are under control, this procedure virtually eliminated rejects due to defects in the bursting charge of TNT.

The earlier procedure under destructive testing was to cross-section one shell selected from every 10 skids. At 32 shells per skid, a defect in one skid would wash out 320 shells, 319 of which might conceivably be good. The system also called for splitting one shell selected from every 30 skids. Thus, a defect found here would condemn 960 shells. When X-ray was used, destructive tests were made only to study peculiar defects and to corroborate questionable indications.

The X-ray inspection schedule at Elwood Ord-

these production load tests was 375±5° F. for 6½ hr. ±¼ hr. Of course, all the above mentioned materials, except that used in the production of the 24S-T80 temper, were cold worked prior to the aging treatment. Table II shows the mechanical properties of the several tempers of clad 24S approved for use in design.

In general, the heat treating procedures used in conjunction with the other new high strength aluminum alloys (R301, R303, and 75S) are almost identical — at least in principle — to those described above for the aged tempers of 24S. The undesirable effect of warpage is also prevalent as a result of solution heat treatment, and the same methods of straightening are used on these alloys as on the more familiar alloys.

The mechanical properties attained by solution and precipitation heat treatments of these alloys are as shown in Table III. It should be noted that all these alloys have mechanical properties superior to the clad 24S-T that has been used almost exclusively by aircraft manufacturers in the United States during the war. Fuller details concerning the 75S alloy are contained in the article on Aircraft Metallurgy by V. N. Krivobok in *Metal Progress* for April 1944, and concerning R301 in an article by Messrs. Fritzlen and Mondolfo in *Metal Progress* for June 1945.

nance Plant called for X-raying 75 shells out of a sub-lot of 1280 shells (40 skids of 32 each). If a *major* defect (serious but not cause for rejection) was found, the 31 other shells on *that particular skid* were all X-rayed.

If, in the original sampling of 75, three or more *major* defects were found, the skids containing those defective shells would then be inspected 100%, and the entire sub-lot submitted for government sampling tests, which includes taking 115 radiographs from the 40 skids.

If five or more *major* defects were discovered, all shells remaining on the 40 skids would be X-rayed, and *only the acceptable shells released.*

If even one *critical* rejectable defect were found, the entire sub-lot would be examined before any shells were accepted.

The 2,000,000-volt equipment was installed at Elwood in time to aid in the quality control of a new type of shell having a much deeper booster cavity than was previously made. This increased the pouring problems, raised serious problems in filling (pouring liquid TNT into the shell and having it solidify without cavities like "pipe" or "porosity"). Such problems were rapidly solved by the thorough inspection by X-radiation.

While it is improper in a metallurgical article to discuss defects that occur in shell loading it may be remarked that they are mostly cavities, porosities, cracked casts and impurities of various types. As in metallurgical inspection there is a threshold value for most observable defects; minor ones cause no troubles in use; major ones call for correction. X-rays of high intensity enable the management to study a large percentage of production non-destructively, to locate operations (or operators) that are producing defectives, and to take the proper corrective steps.

An advantage of higher voltages is that the work may be placed at a greater distance from the tube (8 ft. in this installation), thus subjecting a larger area to radiation, while still maintaining a relatively high radiation strength. Thus, even with thinner sections, high-voltage X-rays are advantageous inspection instruments.

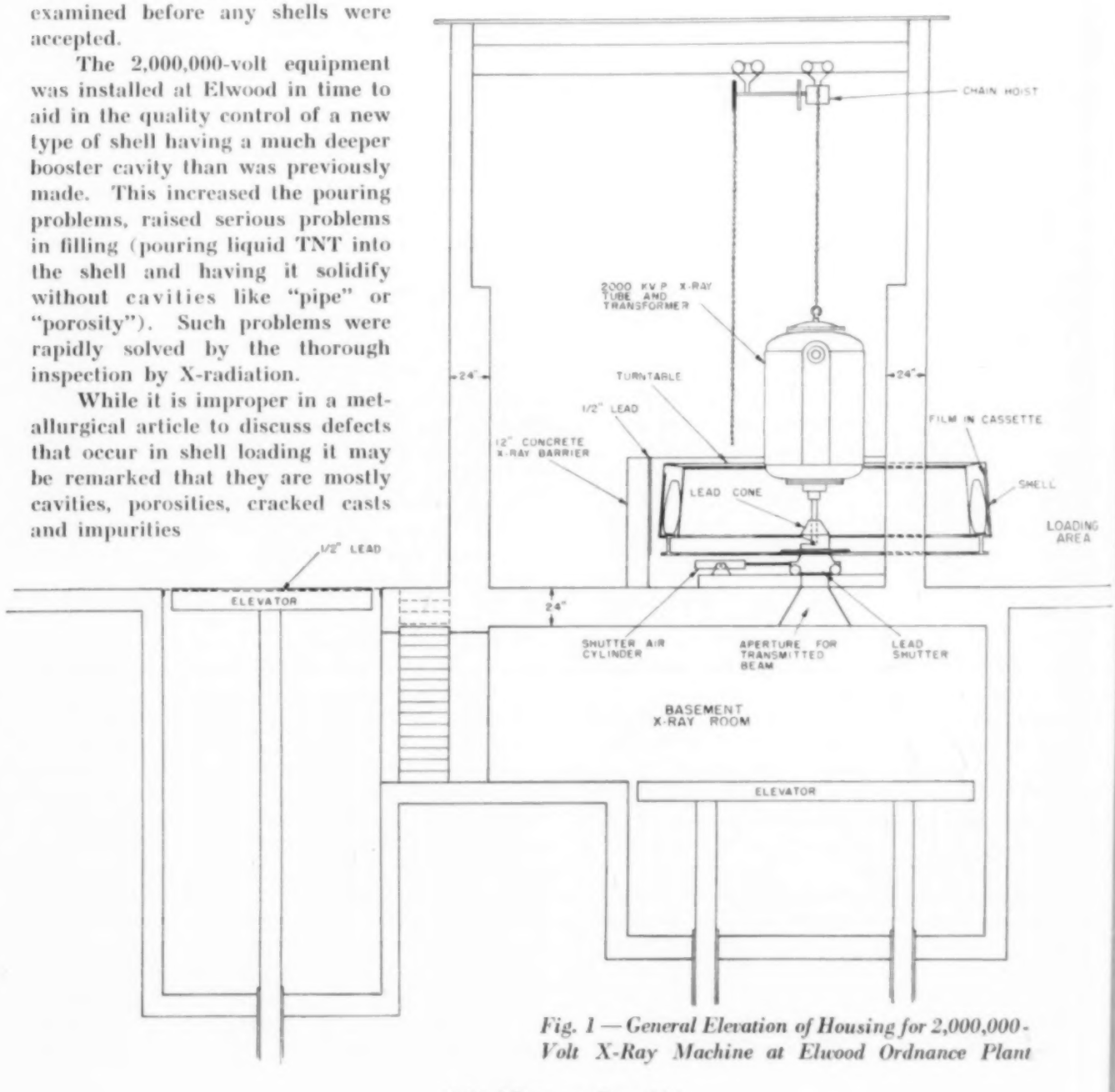


Fig. 1 — General Elevation of Housing for 2,000,000-Volt X-Ray Machine at Elwood Ordnance Plant

Placing the part at a greater distance from the tube also increases detail and decreases distortion of the pictures by reducing the angle at which rays, diverging along the elements of a cone, strike the part.

General Plant Layout

It is perhaps well known that the X-rays from the one million volt tube emanate from the target in all directions. The same is true of this "super-voltage" tube. It is therefore possible to use the horizontal portion of the spherical radiations for radiographing shells and bombs carried around the machine on a continuous ring conveyer or turntable, while the beam transmitted directly through the anode along the axis of the tube was utilized for X-raying of larger shells and bombs in the basement. The general scheme is sketched in Fig. 1, and photographed in Fig. 2. The original plan was to X-ray 250-lb. bombs and 8-in. shells on the main floor, and simultaneously to examine 240-mm. shells and 1000, 2000 and 4000-lb. bombs in the basement. Later changes in plans, however, modified this schedule.

When no operations are under way in the basement, a 12-in. lead shutter cuts off the transmitted beam. (This shutter, on rollers, is clearly shown in Fig. 2.) Items handled in the basement would, as a rule, be those of extremely large size, those too large or too few to handle on the turntable, where size range is limited and production-line technique is demanded for economical operation. The transmitted axial beam is radiographically more penetrating, on an average, than the "reflected" horizontal beam; thus it can handle the larger stuff efficiently.

The use of the transmitted beam in basement operation is a new idea, which to date has been applied only on the more recent 1,000,000-volt installations, but will probably be favored in future high power work. Besides the general advantage of expanding the radiographic capacity of the X-ray unit, it also permits experimental and occasional X-ray exposures without interfering with the production run on the turntable ring. Objects much larger than those adaptable to turntable handling can also be studied.

The 2,000,000-volt unit at Elwood was installed almost at the same time as a 1,000,000-volt unit. The larger was intended primarily for larger bombs and large-caliber shells, on which it offers a considerable advantage in exposure time and film latitude. Although exact comparisons between the two voltages have not been worked out for TNT, some idea of the difference may be obtained from the fact that on 8 in. of steel at 4-ft. focal-film distance, the 2,000,000-volt beam requires just 1/100 (1%) of the time the 1,000,000-volt beam requires.

Use of Lead

Strange as it may seem, in the Elwood installation lead is not actually employed as an integral part of the X-ray head. A lead cone, 10 in. thick, placed on the floor around the anode, comes closest to being a part of the apparatus itself. As indicated in Fig. 1, it has a slot or window cut into one side so as to permit the ammunition on the

Fig. 2 — Crane-Man's View of a Large X-Ray Tube and the Inner Section of the Turntable, Compartmentalized by Thick Lead Plate

ring to be exposed to radiation throughout 180° of its travel. Radiation headed toward the loading area is absorbed by the solid lead in that portion of the cone.

In addition, a series of lead plates called the "primary curtain" has been placed around the window in the cone to produce a uniform density on the film in spite of the varying thicknesses of the shell or bomb.

A lead filter ⅛ in. thick is placed between the object and the film, for two purposes, *(a)* to screen the longer wave lengths, thus increasing film latitude or ability to reveal a range of cross-sections on a single film, and *(b)* to filter out secondary and scattered radiation resulting from the X-rays which have penetrated the ammunition and surrounding partitions.

Lead is also employed in the form of silhouetted diaphragms in the front wall of the turntable compartments which frame each piece of ammunition, thus preventing radiation which does not go through the object from scattering and thereby fogging the film. In addition, a lead shield is placed behind the film and in front of the 12-in. concrete inner wall or barrier. This shielding forms a half-circle, 16 ft. in diameter, 6 ft. high and ½ in. thick, protecting the area outside from the primary radiation, and reducing scattered radiation to a minimum.

The basic protection to personnel consists of this internal concrete wall and its lead shield, plus the 24-in. floor and walls, and the 12-in. lead shutter to stop the transmitted beam when no work is in progress in the basement.

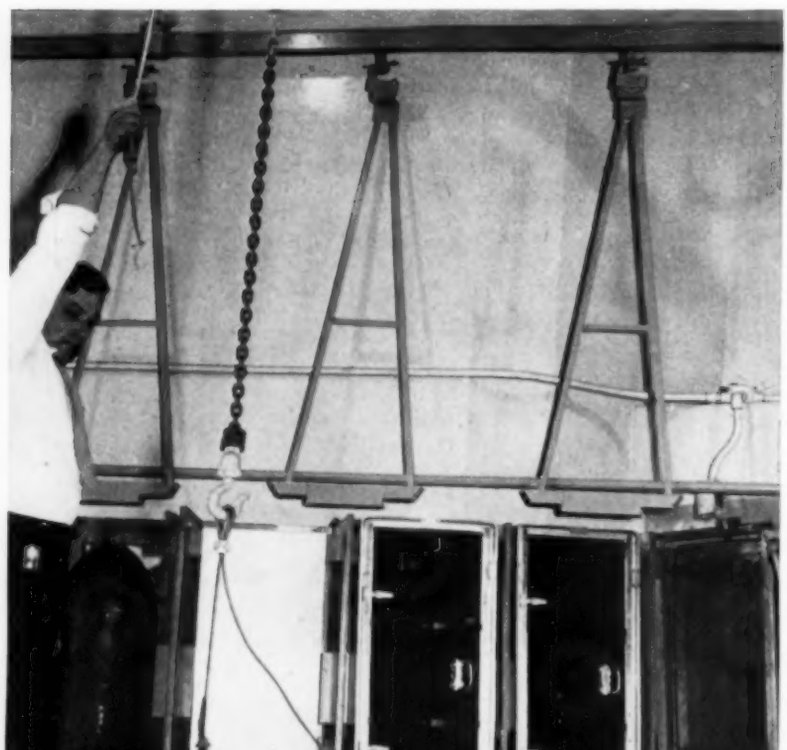


Fig. 3 — Preparing to Hoist a 250-Lb. Bomb Into a Compartment on the Turntable. Note bomb in place immediately in front of operator; next compartment to right (in direction of motion) has ⅛-in. lead filter in place; next two have film cassettes

The X-Ray Machine

General construction of the X-ray tube may be readily comprehended from the description of its one million volt baby brother given, by the Editor of *Metal Progress*, in his "Critical Points" in November 1941:

"It utilizes the fundamental principle of the cyclotron 'atom smasher', namely that electrons shot off at relatively low speed (voltage) from a hot metal cathode are given a succession of swift kicks as they pass through appropriate electrical fields, each kick adding to their energy. Two fundamental improvements are required, however — one, the very compact 'resonant transformer' without an iron core to create the electrical fields, and second, the use of freon gas for insulation (di-chlor-di-fluor-methane to you) with three times the dielectric strength of oil but 1/120 its weight. The electron tube is placed right along the axis of the transformer coils, where the iron core would be expected to be, and the tungsten target blocks off the square end of a water-cooled extension, some 2 ft. out in the clear. Here the sharply focused electron stream is converted into X-rays and they emerge in all directions — in this respect the source resembles a radium capsule. So the tube can be poked through the end of a drum and an entire circumferential seam radiographed at once; or a number of objects set in appropriate fixtures

about this energy center for simultaneous inspection.....It's all very mysterious. Here is a stream of electrons — supposedly particles of electricity — moved along at 1,000,000-volt potential and close to the speed of light, but with the relatively low penetrating power of ¼ in. of human flesh. These electrons hit the tungsten and are stopped cold, but the energy is converted into a 'wave' form (whatever that means) called X-rays which penetrate a foot of steel. Maybe it's the conservation of 'size times penetrating power'; electrons with million-volt velocities have some size but little penetrating power; X-rays have no mass and enormous penetrating power."

It will be understood, of course, that the dimensions of the 2,000,000 and the 1,000,000-volt units are not all simply a matter of multiplying by 2. The steel tank on the 2,000,000-volt unit is 8 ft. long and 5 ft. in diameter; that of the smaller unit is 5 ft. long and 3 ft. in diameter. The entire larger unit — casing, tube, transformer and all — weighs 5100 lb. as against 1800 lb. for the 1,000,000-volt. Both use freon gas as electrical insulation.

of an extension chamber, and cylindrical accelerating electrodes in each of the 24 intermediate sections. The chamber walls and the target are cooled by water. Sandblasting the inside glass walls of the tube has eliminated dangerous field currents which might otherwise arise from the application of increased voltage to succeeding tube sections.

Two exciters are used on the frequency changer. One supplies the motor field, focusing coil and electronic protective relays. The other supplies only the alternator field. The 180-cycle voltage to the high-tension transformer is controlled by adjusting the field current of the direct-current exciter.

The volume of freon insulation is about six times that used in the smaller unit, and is equivalent to about 280 lb. of freon liquid. This gas, under 60-psi. pressure, surrounds both the transformer and that portion of the tube which is inside the steel tank. Two motors and fans located in the transformer circulate the gas during operation to aid in cooling the transformer.

Because of the large volume of freon used, a compressing and condensing unit is supplied to

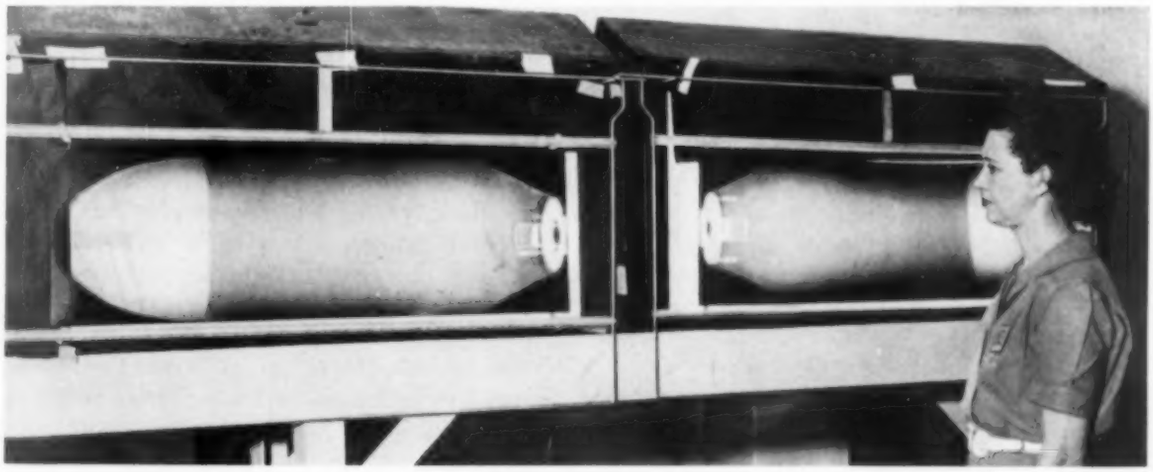


Fig. 4 — Radiograph of 250-Lb. Bombs on Viewer. Film at left shows bad cavitation in top-off of TNT

Two principal factors enabled a machine operating on 2,000,000 volts to be constructed and capable of being housed in a reasonably sized room. One was the development of a large, low frequency resonance transformer into which the long electron ray tube could be inserted; the other was the tube itself, actually a further development of the 12-section fernico-ring design used on the 1,000,000-volt apparatus. Permanently vacuum-sealed, the 2,000,000-volt tube contains 24 intermediate electrodes.

The tube has a filamentary cathode, a copper-backed tungsten target mounted in the lower end

remove and store the gas when repairs are necessary. While a vacuum pump is used on the million volt unit, the condenser is not, since the volume of freon is relatively small and it can be discarded during repairs. The condenser on the two million volt unit is required to cool the freon to a liquid for storing in a cylinder.

A remote control switch allows the operator to raise the voltage gradually and continuously on the tube from a minimum predetermined level to full operating potential.

A significant index by which the 1,000,000 and 2,000,000-volt units may be compared is by the

"half value layer" — that is, the amount of lead or any other substance which may be interposed in the path of an X-ray beam to reduce it to half its original value. Whereas the smaller unit has a half value layer of 3.3 mm. of lead, the larger has a half value layer of 10 mm.

Safety Interlocks

The electrical system of this installation is so thoroughly interlocked with safety devices, and so many systems are connected in series, that it is impossible to produce X-radiation unless all factors are in order. There is the warning bell which sounds in the X-ray room when the unit is about to be operated. If a person is caught inside after the door has been closed, he hears this and has merely to press a button to interrupt the circuit and sound an alarm. Any number of interlocks may be connected in series with the mechanism operating the door to provide reasonable assurance that doors are closed and other factors satisfied before X-rays are generated.

The surge tripper must be de-energized (automatically accomplished by depressing the X-ray "on" button) before voltage can be applied to the primary of the transformer. The switch on the timer must be in the "on" position. Both freon cooler relays must be closed — a condition possible only when both cooler motors are running. The freon pressure relay must be closed. Still further insuring proper operation of the unit is the requirement that the focusing coil relay be closed before the circuit is complete. If water pressure falls, the low pressure "stat" opens, the water relay is de-energized and the X-ray turned off.

Operating the Ring

A total of only nine non-supervisory employes are necessary for smooth operation of the X-ray process as set up at Elwood Ordnance Plant. One unloads exposed film cassettes as they emerge from the X-ray room and identifies the film as having been exposed and the shell as having been X-rayed. The second removes the shells from the ring. The third puts shells on and a fourth checks cassette numbers against shell numbers and places the cassette on the ring. A fifth brings loaded skids with unexposed shells and takes exposed shells from the ring.

In the dark room, one operator unloads films from cassettes as they are borne into the room; a second puts films into hangettes and places these on the developing machine conveyer system; a third places new film in cassettes and changes the external lead letters used to identify sub-lots; while a fourth assists the third and does dark-room utility work.

The X-ray process begins when a lift-truck takes finished shells off the production line and brings them — one skid at a time — to the ring loading section. Here, on that half of the ring which is outside the X-ray room, they are loaded and unloaded from the constantly moving conveyer.

The length of time required for the ring to traverse the interior of the room determines the exposure, and this may be modified by speed reducers on the traction cone. However, as pointed out earlier, the exposure is also affected by the lead shields which form a "primary curtain", screening out part of the primary beam, and by changing the milli-amperage of the tube, which operates from 0.01 to 1.50 ma.

The ring passes through the wall at the rear of the room within a lead-lined tunnel that is fitted with lead-rubber baffles around the exterior ports. The sections or mountings on the ring are arranged with vertical lead shields for each partition, and there are always at least two of these shields in the tunnel at any one time.

The huge door to the X-ray room, 24 in. thick, contains 29,700 lb. of concrete and 800 lb. of mechanism — close to 16 tons complete. An added safety factor is that this door must be closed by hand crank, thus removing any possibility that the mere pressing of a button could accidentally seal a person in the X-ray room, or squeeze him against the jamb.

Borne through the X-ray room with the shells, the films in their cassettes are similarly carried by conveyer from the unloading area into the dark room through a light-tight tunnel. Here an interruption in the production-line system is necessary to place the films on hangettes used in the completely automatic Pako film developing unit, which not only moves the films at a prescribed rate from one solution to another, but also raises and lowers the films while submerged in each solution. The conveyer system on this device also lifts the developed film from the wash tank and carries it through a light-tight tunnel into the viewing room.

Since only a small proportion of the developed films need be saved, most of them are read while wet, having been run through the wash only long enough to permit immediate viewing. This not only saves time on the viewing end but also permits shells to move out faster, since their condition is being checked more rapidly. Reading wet makes possible the use of only a small film dryer, but requires an auxiliary tank to finish washing those films which are to be retained. Films not retained are sold for salvage value.

A Workable Classification of Toolsteels

By C. L. Hibert
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CODING TOOLSTEELS according to chemistry has enabled the San Diego Division of Consolidated Vultee Aircraft Corp. to select correct steels for various tooling applications, and use more surely the proper heat treatments. Simple mark-and-number codes have replaced trade names in the tool design, the heat treating and the purchasing departments as well as in the tool room. Since adoption of the new coding system, tool breakage has been reduced, man-hours of highly skilled labor have been saved in the tool room, and production has been increased.

For our purposes, toolsteels are defined as steels that are used to cut, form, or otherwise alter the principal shape of other materials. As is well known the early toolsteels were plain iron-carbon alloys with a small amount of manganese and silicon, and with impurities such as sulphur and phosphorus held to a minimum. The absence of deleterious elements distinguishes the toolsteel group from ordinary openhearth or bessemer steel.

With the growth and development of modern industry, applications for toolsteels multiply and standards of service greatly increase. As a result of this, the general purpose carbon toolsteels are no longer adequate. During the last 80 years many alloy steels have been developed to meet the continually increasing severity and multiplicity of requirements, and at present there are over 1500 trade named toolsteels in America alone. This diversity would defeat its own ends were it not that for all practical purposes all 1500 may be sub-divided into nine classifications. We therefore have proceeded on the assumption that trade names should be replaced by a coding system, and that this would aid the tool designers, the heat treaters and the tool room, as well as insure proper stocking.

In this classification program we were influenced by one consideration that would not apply in peacetime; namely, an effort was made to select only those steels that contained no great amount of critical metals. Consequently, four groups of toolsteels were selected from a classification by James P. Gill, summarized in the October 1938 issue of *Metal Progress*. These four will fill the needs of aircraft tooling, inasmuch as we do not need hot work die steel. Accordingly a form letter was written to 22 steel manufacturers, requesting the trade names of their steels which fell within these four classifications. Originally there were eleven sub-divisions under the four classifications, but the replies from these companies indicated that only nine sub-divisions were necessary. Later this program was revised to include high speed toolsteels, thus making five major groups with 14 sub-divisions.

Our essential objects in coding toolsteels were three-fold:

1. To correlate trade names with a definite chemical analysis.
2. To correlate heat treating practice, as given by various manufacturers, with representative analyses of the individual groups.
3. To devise designations which would avoid confusion in the shop.

The five groups are designated as follows:

Group 1: General purpose toolsteels; marked with a circle stamp.

Group 2: Oil hardening die steels (non-deforming); marked with a diamond stamp.

Group 3: Silicon-manganese shock resistant chisel and punch steels; marked with a square stamp.

Group 4: High carbon, high chromium punch and die steels; marked with an ellipse stamp.

Group 5: High speed toolsteels; marked with a triangle stamp.

Table I — Classification of Toolsteels (Consolidated Vultee Aircraft Corp.)

Classification		Chemical Limits									Description	Approx. Base, ¢ Per Lb.
Group	Code Mark	C	Mn	Si	W	Cr	V	Mo	Co	Others		
1	Circle 1	0.18 0.25	0.30 0.50	0.10 0.30							S.A.E. 1020	0.10 c.r.‡ 0.05 h.r.
1	Circle 2	0.45 0.55	0.60 0.90	0.10 0.30							S.A.E. 1050, plow steel	0.12 c.r. 0.06 h.r.
1	Circle 3	0.85 1.00	0.30 max.	0.15 0.25		0.25★	0.15★				Carbon toolsteel	0.10 (bar) 0.27 d.r.
1	Circle X	1.50	0.50 max.	0.75 0.85				0.20 0.30			"Graph-Mo" graphitic toolsteel	0.39
2	Diamond 1	0.85 0.95	1.60 1.75	0.20 0.30				0.30★			Oil hardening die steel, non-deforming	0.35 (bar) 0.65 d.r.
2	Diamond 2	0.85 0.95	1.10 1.20	0.20 0.30	0.40 0.60	0.40 0.60					Oil hardening die steel, non-deforming	0.38 (bar) 0.90 d.r.
3	Square 1	0.50 0.60	0.40 0.70	1.00 1.80			0.13 0.25	0.40 0.60			Silicon-manganese punch and chisel steel	0.41 (bar) 1.20 d.r.
4	Ellipse 1	1.50 1.75	0.15 0.25	0.15 0.25		12.00	0.25	0.80 1.00			High carbon-chromium punch and die steel, air hardening	0.60
4	Ellipse 2	2.00 2.25	0.15 0.25	0.15 0.25		12.00	0.25 1.00	1.00		0.50 Ni★	As above, but oil hardening	0.65
4	Ellipse 3	0.90	0.15 0.25	0.15 0.25		1.35 1.60		0.08★		0.35 Ni★	Chromium roller bearing steel, oil hardening†	0.22
5	Triangle 1	0.70 0.80	0.15 0.40	0.15 0.40	18.00	4.00	1.00 1.50				Tungsten type high speed toolsteel	1.25
5	Triangle 2	0.70 0.80	0.25 0.35	0.20 0.40	18.00 18.50	4.00 4.50	1.00 1.75	1.00★	5.00 12.00		Tungsten-cobalt type high speed toolsteel	1.35
5	Triangle 3	0.70 0.80	0.25 0.35	0.20 0.40	5.50 5.75	4.00	1.50 2.00	4.00 4.75			Molybdenum-tungsten high speed toolsteel	0.85
5	Triangle 4	0.70 0.80			5.50 5.75	4.00	1.50 2.00	4.00 4.75	5.00 8.00	0.25 B★	Molybdenum-tungsten-cobalt high speed	0.95

★Optional. †S.A.E. 52100 or equivalent. ‡c.r. is cold rolled; h.r. is hot rolled; d.r. is drill rod.

The above marks, surrounding a central numeral, form the various codes. Small numerals are grouped so as to spread over a definite chemical analysis. For example, in Group 1 "Circle 1" code indicates low carbon steel, "Circle 2" indicates medium carbon steel, "Circle 3" indicates special carbon steel, and "Circle X" indicates graphitic toolsteel.

Such general information is given in Table I, which also contains the limiting chemical analyses. This table is sent to vendors as a procurement specification.

As already stated, the primary purpose of this classification was to eliminate the use of vendor's trade names by our own personnel. Previously it was rather difficult to substitute a steel with a new trade name, equivalent to a formerly used steel and for the same purpose, because certain trade names were used by shop men to describe *all* toolsteels. For instance, when "Super Dooper No. 1" was used for tooling and it was necessary to change to another vendor's steel the substitute was still called by the original vendor's trade name in the shop. "Super Dooper No. 1" then became something of a code, but when the heat treatment for the new steel was entirely different it ran us into trouble.

In the past it had been the practice to identify the steel by stamping on it the vendor's trade mark; under the present system the individual code designations remain the same regardless of the source of supply. Consequently, with all pertinent knowledge cataloged, it is very easy for Vultee personnel to become familiar with Vultee designations and the heat treatment and uses of these selected toolsteels. It also makes for competitive buying, since all major vendors are indicated as an acceptable source of supply.

Toolsteel codes are stamped in letters ¼ in. high on all stock that comes into the tool room. Each drawing for a tool design bears the code of the proper steel to be used in its manufacture, and specifies whether hot rolled, cold rolled, or annealed toolsteel stock, and the desired Rockwell hardness

Table II — Applications of Toolsteels

Kind of Tool	Steel Recommended		Qualities Wanted in Tool	Rockwell Hardness
	First	Second		
Arbor nuts, milling machine	Square 1	Circle 2	Fair hardness, great strength	45 to 52
Arbors, milling machine	Square 1	Circle 2	Fair hardness, great strength	52 to 55
Arbors, lathe	Circle 3	Square 1	Very hard	60 to 63
Boring bars	Square 1	Diamond 1	Fair hardness, great strength & toughness	42 to 46
Broaches	Triangle 3	Diamond 2	Max. hardness, normal distortion, best cutting edges	62 to 64
Broach adapters	Square 1	Circle 3	Fair hardness, machinability	46 to 50
Bushings, guide	Circle 3	Diamond 1	Hard wearing surface, normal distortion	62 to 64
Bushings, screw type	Diamond 1	Ellipse 1	Hardness, wear resistance, min. distortion	60 to 62
Buttons, locating	Circle 3	Diamond 1	Very hard	60 to 62
Centers, lathe	Diamond 2	Triangle 3	Very hard	60 to 63
Chisels, cold cutting, hand or pneumatic	Square 1	Diamond 2	Shock resistance, wear resistance	Edge 53/55 Shank 42/48
Clamps	Circle 3	Square 1	Fair hardness, great strength	46 to 52
Clamp block, for tube bending	Diamond 1	Diamond 2	Max. surface hardness and wear resistance	60 to 62
Collars, milling machine arbor	Circle 3	Circle 1 Case hdn.	Hard, wear resisting case, semi-hard core normal distortion	60 to 63
Collets	Square 1	Circle 3	Hard wearing case, semi-hard core, min. distortion	Hole 61/64 Shank 50/55
Cones, for tube flaring machine	Triangle 3	Circle 3	Max. hard point, strength & toughness, fairly hard shank	Point 60/62 Shank 42/46
Counterbores	Triangle 3	Triangle 4	Max. hardness, min. distortion, best cutting edges	61 to 63
Counterbore pilots	Square 1	Circle 3	Very hard	60 to 62
Counterbore (shank extension)	Square 1	Circle 3	Fair hardness, great strength	46 to 52
Cutters, wood working	Triangle 3	Circle 3	Toughness	56 to 60
Cutting tools, for babbitt and non-ferrous metals	Circle 3	Triangle 3	Very hard, keen cutting edges	60 to 64
Cutting tools, ground after hardening	Triangle 3	Triangle 4	Max. hardness, normal distortion, best cutting edge	62 to 65
Cutting tools, not ground	Triangle 3	Diamond 1	Max. hardness, min. distortion, good cutting edge	62 to 65
Die strippers	Circle 2	Circle 1	Semi-hardness, machinability	28 to 34
Die strippers, compound, harden	Circle X	Circle 2	Fair hardness, normal deformation	46 to 50
Dies, extrusion	Triangle 3	Ellipse 1	Hardness, toughness, min. distortion, wear resistance	59 to 62
Dies, bending & forming, for light work	Diamond 2	Diamond 1	Hardest surface, min. distortion and breakage risks	58 to 62

of the finished tool. After manufacture of a tool, the code again is stamped on the finished product in ⅛-in. letters. If a tool needs reworking, the correct heat treatment may be determined readily by the code designation by consulting the instruction manual.

Recommended steels for specific tooling applications are shown in Vultee's Tool Design Manual. These are reproduced in Table II, on this and the next two pages, and indicate the various perishable tools and dies manufactured by the tool room. Recommended toolsteels are shown as to first and second choice; an alternate steel is included to take care of such a contingency as shortage of stock of the desired size. The charts also show the steel qualities desired for the tooling application and the Rockwell hardness recommended.

This table is very useful for the tool designer who, for example, may have to design a special cold cutting chisel. The information shown by the chart reveals that Square 1 is preferred and that Diamond 2 may be used as an alternate; the qualities desired are shock resistance and wear resistance, and the edge should have a Rockwell of C-53 to 55, and the shank should be selectively hardened to C-42 to 48.

With new heat treating instructions for all given types of steel, improper heat treating equipment would have

nullified the entire toolsteel program; therefore we modernized the department. (See the view on page 341.) The open batch-type furnaces were replaced with five salt bath furnaces, one for high speed with a temperature range of 1900 to 2350° F., a quenching salt bath unit with a temperature range of 1000 to 1300° F., a preheating bath which operates up to 1600° F., and two salt baths for tempering which operate up to 1350° F.

Use of Salt Baths

The advantage of using neutral baths is that surface changes are prevented, all air being excluded during the heating cycle and the brief interval of transfer to the quenching medium. For this reason, parts may be finish-machined prior to hardening, and full skin hardness realized. With the open atmosphere furnaces, it was necessary to rough-machine the tool first and to finish-machine or grind after heat treatment, a costly and inefficient procedure.

In a salt bath, tools come up to a temperature more rapidly than in an air bath due to the more rapid heat transfer. The temperature of a salt bath can be controlled more narrowly, inasmuch as the salts have a high specific heat, and fluctuation in the furnace temperature is negligible.

The instrumentation of these furnaces is of the latest electronic type. The high speed unit is equipped with a "Rayotube" pyrometer. In the old equipment many tools were ruined, thus wasting skilled labor, material and money.

Table II (Cont.) — Applications of Toolsteels

Kind of Tool	Steel Recommended		Qualities Wanted in Tool	Rockwell Hardness
	First	Second		
Dies, for Cu, Al, or brass up to 0.020 in. thick	Diamond 2	Diamond 1	Good cutting edges, min. distortion	60 to 63
Dies, for heavy plate	Diamond 2	Diamond 1	Max. hardness, wear resistance, normal deformation	60 to 63
Dies, for small lots that can be ground	Diamond 2	Diamond 1	Hard, keen cutting edges	60 to 63
Dies, impractical to grind	Ellipse 1	Diamond 1	Hardness, toughness, min. distortion, wear resistance	60 to 63
Dies, thread rolling	Triangle 3	Ellipse 2	Hardness, toughness, min. distortion, wear resistance	60 to 63
Dies, tube swaging	Square 1	Ellipse 3	Hardness, toughness, wear resistance	60 to 62
Drift pins, round taper	Square 1	Circle 3	Shock and wear resistance	46 to 50
Drifts, small	Square 1	Circle 3	Toughness	46 to 48
Drill plates, multiple hole	Circle 2	Square 1	Medium hardness, wear resistance, min. distortion	46 to 50
Follower bar, for tube bending	Diamond 1	Diamond 2	Hardest surface, wear resistance	60 to 62
Form block, for tube bending	Diamond 1	Circle X	Max. hardness, wear resistance	60 to 62
Gage pins	Diamond 2	Square 1	Very hard	60 to 63
Gages, all types	Diamond 1	Diamond 2	Hardness, medium ductility, machinability	60 to 63
Gear hobs	Triangle 3	Triangle 4	Hardness, wear resistance, min. distortion	63 to 65
Guide pins	Diamond 2	Circle 3	Hard wearing surface, normal distortion	60 to 62
Jigs, welded, under 60 lb.	Circle 2	Circle 1	Semi-hardness, machinability	29 to 33
Mandrels, lathe	Circle 3	Diamond 2	Very hard	61 to 64
Mandrels, for tube swaging machine	Square 1	Circle 3	Hardness, strength	55 to 59
Mandrels, link and cable types for tube bending	Square 1	Circle 3	Max. hardness, great strength, wear resistance	59 to 62
Milling cutter bodies, inserted tooth	Circle 2	Circle 1 Case hdn.	Hardness, medium ductility, max. machinability	46 to 50
Milling cutter teeth, inserted	*(a)*	Triangle 3	Max. hardness, normal distortion, best cutting edge	62 to 65
Milling cutters, ground after hardening	Triangle 3	Triangle 4	Max. hardness, normal distortion, best cutting edges	62 to 65
Nuts, clamping	Circle 3	Square 1	Hardness, medium ductility, max. machinability	35 to 40
Punch backing plates	Circle 2	Circle 2	Fair hardness, normal distortion	35 to 40

(a) Composite using "Firthite" Tool Tip.

Advantageous Substitutions

Since adopting the above toolsteel program throughout the San Diego Division, one of the tool rooms has been using the "Diamond" code steel for blanking dies without one failure in service. The standard of quality in this die steel is obtained when it is heat treated to Rockwell C-60 to 61. It holds up in service, per grind, five to ten times as long as the type of steel formerly used. The old type of steel could be hardened only as far as C-55 in order to leave enough toughness in the tools. The "Diamond" steel is tougher at C-60 than the other is at C-55.

One department was having considerable trouble with beading ¼-in. tubing. The beading tools gave a maximum life of only 100 pieces per tool. Twelve of these tools were made out of code "Square 1" steel. Only two were necessary; they have already beaded 35,000 pieces.

Our tool design manual contains a series of charts giving the specifications and sizes of all toolsteels in stock, so designers may know the standard sizes and shapes. These charts have reduced machine operations required on stock. For example, if a tool designer wishes to specify a ¼x1x 2-in. piece he first refers to the chart to determine if the particular size of steel is stocked under the desired code of toolsteel. If not, a size in stock that will fill the same needs is selected. The charts list approximately 1000 sizes.

Two types of graphs were devised for tool designers and heat treaters, indicating the drawing temperatures of each toolsteel for maximum hardness and toughness, and the impact resistance in ft-lb. after various treatments. The charts for high speed toolsteels are reproduced in Fig. 1 to 4, on the following pages.

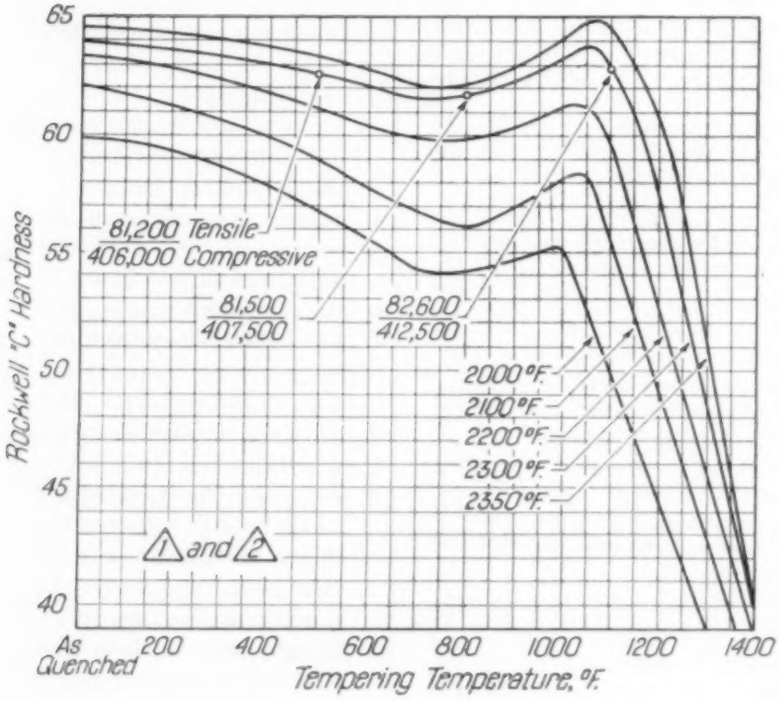
Heat treating data for all the steels grouped into the five classifications were also worked

Table II (Cont.) — Applications of Toolsteels

Kind of Tool	Steel Recommended		Qualities Wanted in Tool	Rockwell Hardness
	First	Second		
Punches, center	Circle 3	Diamond 2	Fair hardness, reduced brittleness	57 to 60
Punches, center	Square 1	Circle 3	Shock and wear resistance	Point 56/59 Shank 46/48
Punches, for Cu, Al, or brass up to 0.020 in. thick	Diamond 2	Square 1	Good cutting edge, soft body, min. distortion	60 to 63
Reamers	Triangle 3	Triangle 4	Max. hardness, normal distortion, best cutting edges	63 to 65
Rivet sets	Square 1	Diamond 2	Fair hardness, shock resistance, normal deformation	47 to 52
Rivet setting tool, forming end of	Square 1	Diamond 2	Fair hardness, shock and wear resistance	40 to 43
Rolls, form or contour	Ellipse 3	Circle X	Hard wearing surface, toughness, min. distortion	58 to 62
Saws, teeth for cut-off saws	Triangle 3	Triangle 4	Max. hard cutting edges, soft shank	62 to 65
Saws, for holes	Triangle 3	Triangle 4	Max. hardness, best cutting edge, min. distortion	60 to 62
Screw drivers	Square 1	Diamond 2	Strength, toughness, shock and wear resistance	53 to 55
Shear blades	Diamond 2	Triangle 3	Fair hardness, reduced brittleness	53 to 56
Spot facers	Triangle 3	Triangle 4	Hardness, best cutting edge, min. distortion	60 to 62
Stamps, lettering and numbering	Circle 3	Diamond 2	Hardness, reduced brittleness	60 to 63
Stripper fingers, long thin	Diamond 1	Square 1	Fair hardness, normal deformation	Fingers 58/62 Body 50/52
Taps, ground or not	Triangle 3	Triangle 4	Max. hardness, wear resistance, min. distortion	63 to 65
Templates, sheet steel	Circle 2	Diamond 2	Hardness, wear resistance	63 to 66
Tool holders	Square 1	Circle 1 Case hdn.	Hardness, medium ductility, max. machinability	40 to 45
V-blocks	Circle 2	Diamond 2	Hard wearing surface, normal distortion	60 to 64
Vise jaws	Circle 3	Circle 1 Case hdn.	Hard wearing surface, min. distortion	60 to 64
Wrenches, open end, socket or special	Square 1	Circle 2	Fair hardness, great strength, toughness, ductility	40 to 45 45 to 50 38 to 41

out and recorded to insure, as nearly as possible, the maximum utility of the tools made from them. By analyzing the bulk of the information supplied by manufacturers, it was possible to write appropriate heat treating instructions for the various codings. These instruction sheets follow. (Instruction sheets for high speed have been omitted, as they parallel closely the material published in Metals Handbook.)

Fig. 1, Below — Hardness of "Triangle 1" (18-4-1) and "Triangle 2" (18-4-1-Co) Oil Quenched and Drawn at Various Temperatures. Representative ultimate strengths in tension and compression are shown for the 2300° quench. Quenching in air will lower the hardness values only slightly



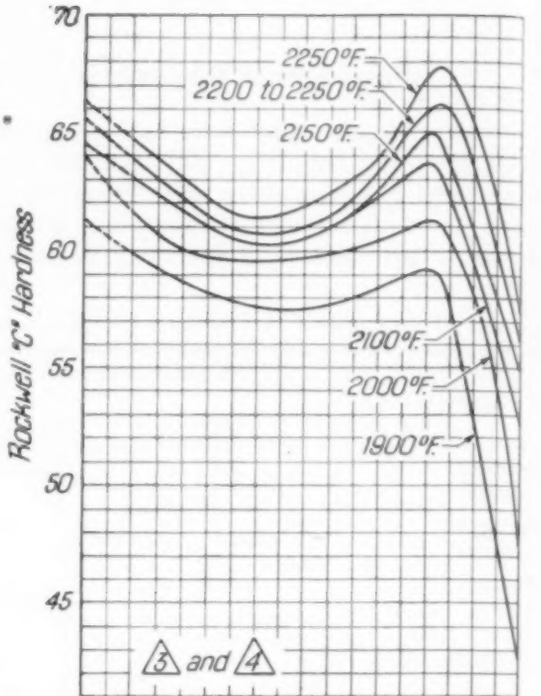


Fig. 2 — Hardness of "Triangle 3" (W-Mo) and "Triangle 4" (W-Mo-Co) High Speed Steels, Oil Quenched and Drawn at Various Temperatures. Quenching in air will lower the hardness values only slightly

Instruction Sheets

Group I **Low Carbon Steel** **Circle 1**

Carburizing grade only;
characterized by high warpage and low strength.

Uses — This is definitely not a heat treatable steel and is only included to differentiate it from the other toolsteel groups, and thus avoid confusion in the shop. This steel has been used to a great extent for blanking dies because of its easy machinability. The steel is then carburized by either pack hardening or liquid carburizing. Surfaces not requiring the carburizing treatment are shielded by "copper resist paint". Now and then it may be used for tools for short runs and should not be used for high production blanking dies.

Normalizing — Heat to 1625 to 1675° F., then cool in still air.

Annealing — Heat to 1575 to 1600° F. Cool in furnace to 900° F. or less, then cool in air.

Hardening (Carburizing) — Heat to 1575 to 1600° F. Quench in water. In order to refine the grain of the case and the core the following treatment is recommended:

Operation 1: Carburize at 1650° F., cool in air, or quench from the pot or box (water or oil quench).

Operation 2: To refine the core, heat to 1550° F., quench in oil.

Operation 3: To refine the case, heat to 1450° F., quench in water or oil.

Tempering — Heat to approximately 1150° F. and cool in air (for 70,000-psi. tensile strength).

Group 1 **Medium Carbon Steel** **Circle 2**

Medium warpage; medium strength; medium wear resistance; oil hardening.

Uses — The primary use of this steel in the aircraft shops has been for blanking dies.

Normalizing — Heat to 1525 to 1575° F., then cool in still air.

Annealing — Heat to 1450 to 1475° F. Cool slowly in the furnace to 900° F. or less. Below 900° F. this steel may be cooled in still air.

Hardening — Heat to 1500 to 1550° F. Quench in circulating oil at room temperatures.

Tempering — Heat from 600 to 950° F., depending on the requirements for strength, hardness and toughness. After soaking at the tempering heat the steel may be cooled in air.

Group 1 — High Carbon Toolsteel — Circle 3

Water hardening; low wear resistance; high warpage; no red hardness; shallow hardening.

Uses — High carbon toolsteel has wide application for blanking, drawing, heading, trimming, embossing, stamping, engraving and coining dies. It is also well adapted to a variety of edged tools such as punches, cutters, shear blades, special purpose knives, chisels or similar applications where a hard surface or keen edge is required in connection with a shock resisting core. Also it may be used for drill bushings, locating pins and gages. Tool designers may call out this steel for practically all purposes in an emergency, if the special alloy toolsteels in the other groups are out of stock. However, a proper heat treatment is necessary for the different tools depending on their design and purpose. This steel will yield a surface hardness of C-62 with proper heat treatment.

Heat Treatment — Annealing temperature, 1375 to 1410° F.; hardening temperature, 1420 to 1550° F.; quenching medium, water of room temperature, drawing temperature, as required, from 212 to 700° F.

Annealing is carried out by bringing the tool very slowly to 1375 to 1440° F. Hold at temperature until the steel is heated through, and then permit it to cool slowly, preferably in the furnace. The tools should be packed in a closed box or pipe with some material such as cast iron chips or spent charcoal, to prevent scaling.

Hardening — The tool, especially an intricate die, should be slowly warmed to about 700° F., then placed in a furnace at a little under 1100° F. and held until uniformly heated. The furnace temperature should then be raised slowly and uniformly to the proper quenching temperature. Furnace atmosphere should be "slightly reducing" in order to reduce scaling as much as possible.

As soon as the tool has reached the hardening temperature, it should be withdrawn, promptly quenched and kept immersed until cool enough to handle with the bare hand. Water or brine maintained at 70° F. is the usual quenching medium.

Tools should be hardened at the lowest temperature that will give the desired hardness. It is necessary to increase the furnace temperature as the size of the tools increases, but as the tool size goes up there is a decrease in both the maximum surface hardness and depth of hardness when quenched from a given temperature.

Drawing — Draw the temper immediately after hardening. This is most important. Tools are drawn or tempered to relieve hardening strains, to obtain the proper hardness and, most important, to give the tool greater toughness. All tools, regardless of service, are benefited by the tempering operation. The temperatures range from boiling water (212° F.) up to 700° F. The length of time at the drawing temperature has a decided effect on the hardness. Maximum toughness is not reached until the tool has been held considerably longer at drawing temperature than the time needed at the hardening temperature. All tools, no matter how small, should be held at temperature for at least a half-hour; larger tools need a longer time. Tools subjected to impact may require an overnight draw.

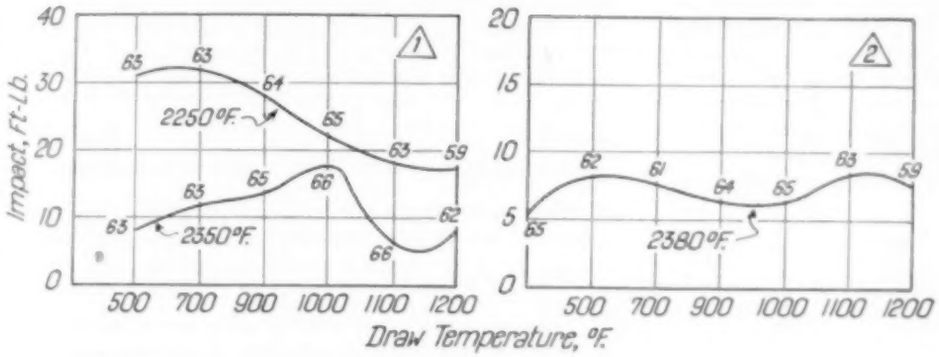


Fig. 3 — Impact and Hardness Values for "Triangle 1" (18-4-1) and "Triangle 2" (18-4-1-Co) High Speed Steels, Oil Quenched After 2 Hr. at Heat and Drawn as Shown. Izod test on 0.505-in. round specimens

Group 1 — Graphitic Carbon Steel — Circle X

Oil hardening; medium wear resistance; medium shrinkage; non-deforming; machinable; non-seizing.

Uses — This is a general purpose toolsteel where the ease of machining makes for low cost tools for short runs.

Normalizing — Heat slowly to 1600° F. and hold until all parts are soaked through. Remove from furnace and cool in air.

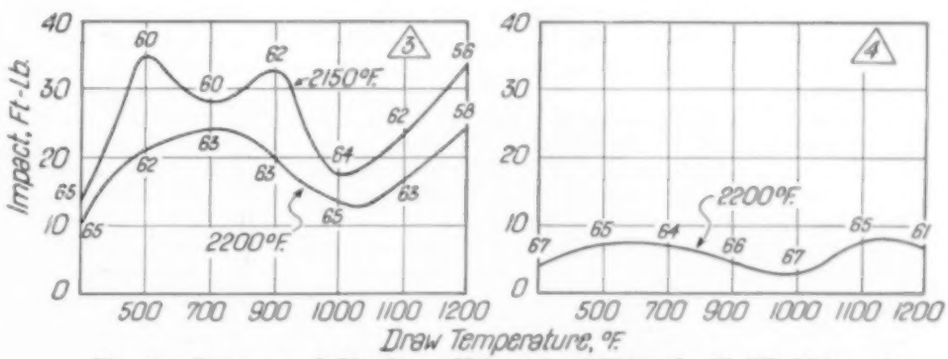


Fig. 4 — Impact and Hardness Values for "Triangle 3" (W-Mo) and "Triangle 4" (W-Mo-Co) High Speed Steels, Oil Quenched After 2 Hr. at Heat and Drawn as Shown. Izod test on 0.505-in. round specimens

Annealing — Heat to 1450° F. Hold until heated through. Cool at 20° F. per hour to 1150° F. and remove from the furnace. A maximum of Brinell 212 hardness results from this treatment. "Circle X" contains 0.50% free graphite after annealing. To rework hardened "Circle X", anneal at 1300° F.; this is below the critical temperature, so the graphite content remains undisturbed, yet the steel is soft enough for easy machining.

Hardening — For average conditions, the following temperatures should be used for solid sections:

½ to 1-in. rounds: Heat to 1475° F. and quench in oil. 1 to 2-in. rounds: Heat to 1500° F. and quench in oil. 2 to 4-in. rounds: Heat to 1525° F. and quench in oil. 4 in. and up: Heat to 1550° F. and quench in oil.

The above temperatures are for a uniform section. If light and heavy sections are in the same piece, the lowest temperature which will give a suitable hardness should be used. For pieces having hollow centers it is advisable to quench in agitated oil, or at least move the piece being quenched through the oil to provide circulation. To minimize grinding after hardening, atmospheric controlled furnaces or neutral salt baths should be used.

Tempering temperatures will give the following hardness (Rockwell):

300° F.	C-64	800° F.	C-50
400	63	900	46
500	61	1000	40
600	58	1100	36
700	53	1200	26

Occasionally "Circle X" is used in a normalized condition on applications which do not require much hardness.

Group 2 **Diamond 1 & 2**

Oil-Hardening Die Steels ("Non-Deforming")

Oil-hardening, low wear resistance; medium toughness; low warpage; no red hardness; medium deep hardening.

Uses — Oil-hardening toolsteel was developed for use where it is desirable to maintain low distortion and small dimensional changes and at the same time have a good combination of hardness and toughness. It is deep hardening and will stand many regrinds without having to go back to the heat treating department. It is used for tools that cannot be ground after hardening, due to their complicated form, and for all tools demanding a keen, durable cutting edge.

It is widely used for general purpose tools such as broaches, drill bushings, hobs, knurling tools, reamers, taps, cold forming and bending dies, master tools, forming rolls, intricate cold-working dies, thread roller dies, master dies and gages.

Annealing — Heat slowly and uniformly to 1475 to 1550° F. Hold at this temperature for a sufficient time to obtain complete refinement of grain — 2 to 5 hr., depending upon the size. Cool in furnace or in a medium that will permit uniform and slow cooling. To avoid surface decarburization, it is always advisable to pack anneal. A minimum of movement or distortion of finished machined tools results from an anneal at about 1380° F., after machining and before hardening.

Hardening — Heat the steel very gradually and uniformly to about 1200° F., then raise more rapidly, but still uniformly, to the quenching temperature of 1450 to 1500° F. Hold at this temperature and quench in oil; remove from the quenching medium while still warm (212 to 300° F.) and draw at once.

Tempering — Draw tools immediately in oil or salt to the desired temperature. Hold at temperature from 30 min. to 2 hr. Cool in air or oil.

It will be noted that, when raising the drawing temperature, the hardness decreases rather rapidly to approximately 500° F. Therefore, when *hardness* is the main requirement, no drawing temperature over 465° F. should be used. Small cutting tools, like thread cutting tools, are normally drawn at 320 to 390° F.; broaches and reamers at 390 to 465° F.; coining dies at 465 to 500° F.

Correctly annealed, hardened and drawn at 390° F., this steel has practically no change in volume from its size in the annealed condition.

Group 3 **Square 1**

Silicon-Manganese Punch and Chisel Steels

Medium wear resistance; medium toughness; medium warpage; medium hot hardness; medium deep hardening. Leaf springs. A water hardening and inexpensive steel for cold cutting.

Uses — This steel was developed primarily for shock-resisting tools in which a combination of toughness with hardness is required. "Square 1" is recommended for severe or unusual service in such parts as hand and pneumatic chipping chisels, shear blades, calking tools, rivet sets, beading tools, punches, and for all uses where light or heavy tools are subjected to drastic and repeated impact at normal temperature.

Care is necessary in heating, as all silicon steels are liable to soft skin.

Parts made from it should always be quenched in oil when they are of intricate nature. However, with care, it may often be quenched in water. Either treatment develops the combination of high strength and toughness that is characteristic of this toolsteel.

Annealing — "Square 1" may be annealed by heating in the furnace, but pack annealing is preferred because of the tendency of this steel to decarburize (soft skin). The piece should be heated slowly between 1425 and 1475° F. and held about one hour for each inch of thickness. To obtain best machinability, cool slowly to 800° F.

Hardening and Tempering — When the piece is to be quenched in oil it should be heated slowly and uniformly to between 1625 and 1650° F. When it is to be quenched in water, heat slowly and uniformly to between 1550 and 1600° F., or about 50 to 75° F. lower than when quenched in oil. (This avoids danger of cracking.) The higher oil quenching temperature improves the strength, ductility, and shock resistance. This steel is tempered between 400 and 650° F., depending on the service desired.

Shear blades are larger than ordinary tools and therefore require different heat treatment. After forging and annealing the blades are machined. Excepting short or small blades, they should be sus-

pended vertically and heated to 1200° F. in a preheating furnace, and are then transferred to the hotter furnace and brought up to between 1625 and 1650° F., after which they are oil quenched vertically.

For pneumatic chisels made of this grade of steel, recommended procedure is as follows: Turn the shank from annealed stock. Preheat the opposite end to about 1200° F., then heat to approximately 1800 to 1900° F. and forge out the cutting edge. Cool slowly. Preheat the entire chisel to approximately 1200° F., then heat to between 1600 and 1650° F. and quench in oil. Temper to about C-43 hardness throughout. Grind the shank to finish dimensions. Heat about 3 in. of the thin cutting end of the tool to between 1600 and 1625° F. and quench the entire chisel in oil. (If water is used, the quenching temperature should be about 1500° F.) Temper the entire chisel immediately at 450 to 550° F.

When making rivet sets, it is recommended that the shank be turned from annealed bar stock and the entire set quenched and tempered at temperatures recommended above. Grind shanks and die end to finish dimensions. Shank may then be redrawn at a higher temperature for greater impact strength.

Group 4 **Ellipse 1 & 2**

High Carbon, High Chromium Punch and Die Steels

High wear resistance; low toughness; low warpage; high hot hardness; deep hardening; high compressive strength. For durable tools, mandrels, punches, dies and shears for cold work; for cutting tools on non-ferrous materials.

Uses — High carbon, high chromium steel is a high production die steel that hardens satisfactorily in air ("Ellipse 1"). Its wearing and cutting capacity in the form of dies is considerably better than high speed steel and several times better than carbon steel or oil hardening steels. "Ellipse 1", the air hardening type, is tougher and deforms less in hardening than "Ellipse 2".

It is used for cutting and forming dies such as lamination, trimming, blanking, stamping, cold forming, extrusion, drawing, swaging, pressing, thread rolling, coining, shearing, compressing, slotting dies, and for many other similar purposes. This steel is also recommended for some types of punches, rolls, plug gages, ring gages, taps, burnishing tools, bushings, reamers, broaches, lathe centers, spinning tools, shear blades, and many other special operations where operating conditions are unusual.

Annealing — Proper annealing temperature is 1650 to 1700° F. To avoid surface decarburization, box anneal the steel, packing in lime or used carburizing compound. Keep at temperature for about 3 hr. and cool at a rate of 15 to 25° per hr. The furnace may be shut off and this material should be allowed to cool in the closed furnace to 600° F.

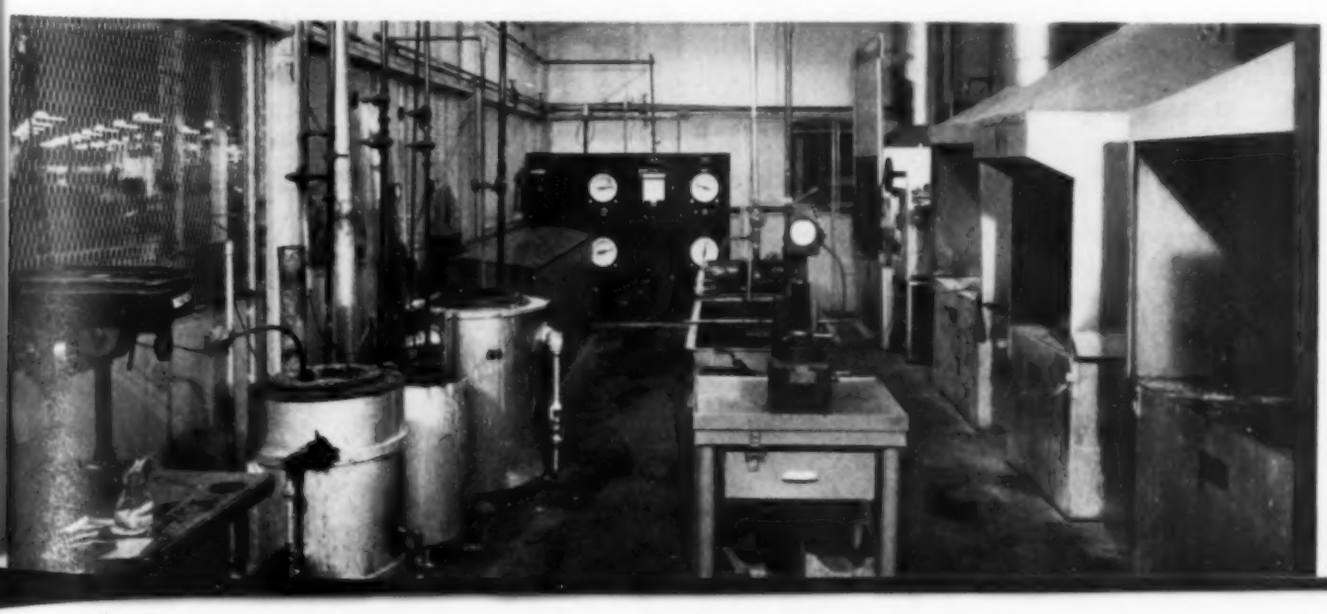
Strain Annealing — To avoid distortion in hardening and to relieve strains, it is advisable to anneal the tool after machining and other cold work has been done and before hardening. The best temperature is 1200 to 1300° F., with sufficient time at heat to assure proper penetration.

Heat Treatment — "Ellipse 1", the air hardening type, is a safe steel to harden, since little distortion results. This permits a high degree of accuracy in the finished die or tool. It is necessary, however, to protect the surface from decarburizing by pack hardening or by a controlled atmosphere. High carbon, high chromium steels absorb heat very slowly, and require considerable time for maximum solution of the carbides. It must be preheated slowly and held at temperature longer than other toolsteels; therefore, pack hardening or salt bath hardening is recommended to give uniform and satisfactory results.

Recommended temperature ranges are as follows: Annealing, 1650 to 1700° F.; preheating, 1200 to 1300° F.; hardening in air, 1825 to 1875° F. for "Ellipse 1"; hardening in oil, 1800 to 1850° F. for "Ellipse 2"; drawing, 300 to 1000° F.

"Ellipse 1" steel may be hardened in oil from 1800 to 1850° F., although this should be advisable only for extremely large pieces. Air hardening gives greater toughness and will result in less distortion and a tool less sensitive to grinding stresses. Blast cooling yields greater hardness than cooling in still air, but carries a greater risk of distortion. The surface hardness obtained is directly dependent on the temperature and heating time, and the dimensions of the piece.

Drawing — This steel may be drawn at 350 to 950° F. without losing much surface hardness. The longer time the tool is drawn at about 925° F. the greater the toughness, with no loss of surface hardness. Drawing "to color" should be avoided. Drawing is best done in oil, lead or salt bath. Tools should be held at the actual drawing temperature at least one hour and preferably longer; large intricate dies and tools need at least two hours at heat. The tools should be drawn immediately after hardening as cracks may otherwise occur due to hardening strains.



Charles Holmes Herty, Jr.

Researcher in Steel;

Newly Elected President

American Society for Metals

President, A.S.M.

BACK IN 1934, when CHARLES HERTY went to work for the Bethlehem Steel Co., he had the uncomplicated title of Research Engineer. But those days are past, and today, if you ask him what his official title is, he tells you — pausing occasionally for breath — that he is Assistant to Vice-President on the staff of the Vice-President in Charge of Steel Plant Operations. Whenever possible, his associates at Bethlehem shorten this to "CHARLIE". Regardless of titles, however, HERTY is best known in this country and abroad as the man most responsible for the modern technique of making clean, reliable openhearth steel.

It has never been exactly clear to anyone what transpires chemically during steelmaking, and even the most skillful openhearth producers operate on a number of rules of thumb which are based more on supposition and theory than on precise knowledge. One of the unhappy results of making steel by dead reckoning was that an unpredictable amount of "dirty" steel was produced which could not meet the increasingly strict quality requirements of important users. It was estimated that this condition put an extra expense of about $40,000,000 a year on the steel producers, much of which might be saved if a method of producing cleaner metal could be found.

For this reason a group of about 30 interested steel companies entered into an agreement with the U. S. Bureau of Mines and the Carnegie Institute of Technology, and established the Metallurgical Advisory Board in Pittsburgh in 1926. This last selected Dr. HERTY to direct an investigation into "the physical chemistry of steelmaking" and financed same. By 1932 most of the successful results of this research were in the hands of the sponsors, and the published findings were enthusiastically acclaimed by prominent metallurgists in both Europe and America. It is characteristic that his reports were so clear and well-prepared that operating steel men found them easy to comprehend, and simple to apply. The secret of this successful presentation is that HERTY knows his way around a steel plant; he can make a heat himself to verify laboratory findings, and — equally important — he can speak the openhearth man's language.

For this and many other outstanding performances, Dr. HERTY has been generously honored by his profession, yet he carries his accomplishments and honors lightly. A person about to meet him for the first time might expect to find him engrossed in his special subject. HERTY does not fall into that too-numerous group. In conversation he is alert, humorous and comfortable to talk to. He is interested in many things and seems undismayed if the talk shifts from the effect of deoxidation on the aging of mild steel to some more general subject such as the future of the No. 2 iron in golf. A smoking-car acquaintance making casual conversation with HERTY might be apt to classify him as a moderately successful business man in almost any line; he could even pass as an athletic coach or a gentleman farmer. He bears none of the comic-strip labels of high learning and doesn't satisfy the popular conception of a scientist who has published nearly 100 technical papers and been awarded the Sauveur Medal, the Hunt Medal, and the Clamer Medal.

HERTY, who is 49 but seems younger, is quite happy to be a metallurgist, and views with almost youthful enthusiasm the advances and improvements that his profession is bringing about in people's lives. He says, however, that he has always liked whatever he was doing, and he thinks it likely that if he had been brought up to be an undertaker, for example, he would have undoubtedly carried out the functions of that ancient profession with seemly diligence.

Actually, he had little chance to be anything else but a worker in the stuffs the world is made of, for his father was one of the country's distinguished chemists who did well both as a professor of chemistry and as a business man in the chemical industry. In 1915 he was President of the American Chemical Society, and during the 10 years prior to his death in 1938, he developed the method of converting the once-useless southern slash pine into paper, thereby greatly advancing both the paper industry and the economic development of the South.

CHARLES HOLMES HERTY, JR., was born in 1896 in Athens, Georgia, and to this day he has never had reason to waver in his pride at being a Southerner. His forebears were likewise proud of their native Georgia, and, more remotely, of their ancestral Scotland. HERTY's grandfather, BERNARD HERTY, was a captain in the Confederate Army, and it wouldn't be surprising if HERTY doesn't have

a little bundle of Confederate paper money and bonds with most of their coupons still attached.

As a child, HERTY made four trips with his family to Europe on a schedule that must have been planned by a numerologist, for they were undertaken when he was, respectively, 2, 4, 8, and 16 years old — a geometrical progression of undoubted significance in that CHARLIE was the only member of his family who never became seasick. When he returned from his second trip, aged four, he and his brother could speak nothing but German; in relearning English they clung to their thick accent and the inverted German sentence structure and sounded very much like *Weber & Fields*. During his trip as a 16-year-old, HERTY won a tennis tournament in Ireland, but the prize he received left him so cold that he gave it away to a girl he'd never seen before. These early influences are set down here to serve as a possible index to his mature character.

The first quickening of destiny in the young HERTY occurred at his 12th year when, cloistered in the cellar, he compounded a mixture of flour, impalpable North Carolina brick dust, potassium permanganate, and certain other chemicals. These combined resoundingly, thus bringing his bent for chemistry forcibly to his father's attention.

In due course, then, after attending the Asheville School in Asheville, N. C., he studied chemistry, played short-stop, and strummed the guitar at the University of North Carolina, receiving his B.S. in 1918. He joined the Army that summer, a private in the Chemical Warfare Service. Shortly after he reported for duty, an officer told him to go fetch a Stillson wrench that was lying on an I-beam. He brought back the wrench, but first he had had to ask someone *(a)* "What is a Stillson wrench?" and *(b)*, "What is an I-beam?" He ended his army career in 1919 as a sergeant in the Ordnance Department. HERTY says that the nearest he came to combat was the occasion when a corporal, who was slightly upset at having his weekend pass refused by SERGEANT HERTY, threw a knife at him. It missed.

After the war he went to Massachusetts Institute of Technology and got his M.S. in Chemical Engineering. Parts of 1921 and 1922 were spent at M.I.T.'s post-graduate Buffalo Station School of Chemical Engineering Practice, and in 1924 he received his D.Sc. There followed two more years at the Buffalo Station School, after which he became physical chemist for the U. S. Bureau of Mines in Pittsburgh. It was here, between 1926 and 1931, that he had charge of the problem, mentioned before, of investigating the physical chemistry of steelmaking. In 1934 the Metallurgical Advisory Board decided that the investigation had reached the point of diminishing returns, and he decided to join the Bethlehem Steel Co.'s staff.

HERTY has been married twice, the first time in 1922, and has four children. His daughter DOROTHEA, the oldest, is in the Waves, and the second child, CHARLES III, is a radioman in the Navy. Another daughter, KATHLEEN, is 13, and devotes her energies to horseback riding and to men in the 13-to-16 age bracket, while the baby is five-year-old TIMOTHY who likes to take things apart. The present MRS. HERTY was KATHLEEN MALLOY; HERTY met her in California in 1929 — "purely," he says, "by happenstance".

The HERTY FAMILY live in a large house on a farm he owns near Bethlehem. He rents out the farmland, retaining enough open field near the house to accommodate his daughter's horse, and a woodlot which serves to satisfy an inherited admiration for trees. He plays bridge, has a golf handicap of 16, and is said to be a man who can bet a pair of sevens so convincingly that many an opponent has decided to fold with a straight.

CHARLES HERTY, JR., has always been quite active in the work of his professional societies, and has also been the recipient of the highest honors that these societies bestow. In addition to having been awarded the Sauveur Medal of the [illegible], the Hunt Medal of the A.I.M.E., and the Clamer Medal of the Philadelphia Technical Society, he delivered the Howe Memorial Lecture in 1940 and he gave the Campbell Memorial Lecture in 1931. He is currently a director of the Mining & Metallurgical Engineers, and president of the American Society for Metals. Members of these groups have admiringly remarked on two of HERTY's characteristics; first, his energy in whatever he undertakes, and second, his willingness to rise upon his feet and debunk dubious or nonconstructive proposals.

One of his fellow metallurgists particularly relishes the way that HERTY faithfully carries out the traditional duties on the occasions when he has to preside at a dinner or a meeting. He realizes that there are times when custom requires that the speaker preface his serious remarks by being reminded of the two Irishmen. To meet this unavoidable requirement, HERTY has equipped himself with a couple of standard, well-tried, sure-fire ancient anecdotes. Naturally, both of them are about the South and involve an old colored retainer named Pompey and a back-county politician. Since he *has* to tell these stories, he tells them very well, and when they are over, CHARLIE heaves a sigh of relief, puts on his glasses, readies his notes, and is happily launched into the business of the evening.

E. C. MCDOWELL, JR.

Bits and Pieces

A place for metallurgical and production ideas; an A.S.M. book of your choice for publishable items

Template for Checking Modulus of Steel

IN BITS AND PIECES in last May's issue was a "Chart to Check Accuracy of Automatic Load-Strain Diagrams" by Amiel Gelb. Such a nomographic method may be highly suitable for non-ferrous alloys having a wide range of values for modulus of elasticity, but for steel it can be done with a simple template such as is used for marking the offset intercepts for yield strength. Although a separate one is needed for each scale of the recorded load-elongation curve (that is, for each size specimen, load range and strain magnification) its construction takes no longer than the analysis of a single diagram.

The template shown herewith has a horizontal base line *OB*, with a modulus line *OP* at an angle corresponding to the slope of the nominal modulus (29,000,000 psi. for steel) for the appropriate scale. Parallel to *OP* are drawn several offset lines (0.01, 0.10, 0.20%) used to locate "yield strength". The load-elongation curve for a given test — recorded on semi-transparent paper — is placed over the template with the straight (elastic) portion aligned over the modulus line *OP*, and the offset yield intercepts are marked. A mere glance at the angular relationship between the base line of the diagram and the base line of the template indicates any gross error in the apparent modulus of elasticity.

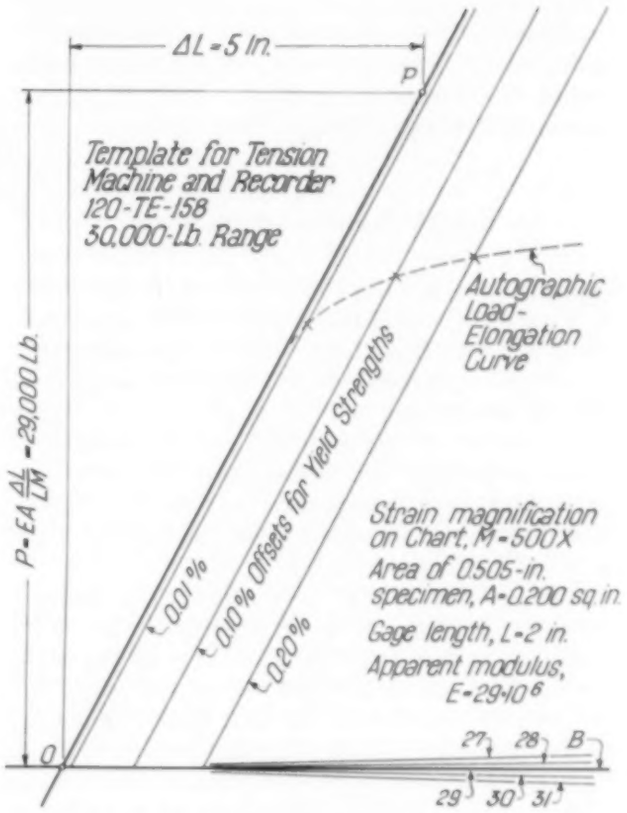
For instance, for a standard 0.505-in. specimen with a 2-in. gage length, 30,000-lb. load range and strain magnification of 500, the template is constructed as follows: On a sheet of recorder paper (which may be the first test diagram of a series) mark an origin on the base line. Substituting the numerical values in the formula

$$P = EA\left(\frac{\Delta L}{LM}\right)$$

where P is the load at strain of ΔL in. on the paper
E is the modulus
A is the cross-sectional area
L is the gage length
and M is the strain magnification

and taking $\Delta L = 5$ in. for convenience, we get:

$$P = \frac{29{,}000{,}000 \times 0.200 \times 5}{2 \times 500} = 29{,}000 \text{ lb.}$$



Template for the Rapid Location of Yield Strength Values on Stress-Strain Diagrams of Steels Which Show no "Drop of Beam", With the Simultaneous Check of the Apparent Modulus of Elasticity

(This obviously is the modulus divided by 1000, which simplifies the procedure for the standard specimen and most common strain magnification. In practice, other selections of ΔL will suggest themselves for other cross-sectional areas to provide similar simplicity.)

Point *P* is located on the sheet by means of the calibration chart for the 30,000-lb. range and on the vertical at $\Delta L = 5$ in. to the right of the origin, and the two lines *OB* and *OP* transferred to a plain sheet of paper, together with parallel lines for the desired offsets. Rather heavily inked lines are desirable for the base and modulus lines. Each template should be properly labeled for future use, including machine dial number and recorder range, strain magnification, specimen

size and area, nominal modulus and offset values.

The template's usefulness is increased by the secondary base lines through the origin at angles to represent the ordinary range of modulus values. This serves as an indicator for the rejection of defective tests. It should be noted that the offset increments for yield strengths are measured parallel to the primary base line and they become inaccurate as the apparent modulus value departs from the nominal modulus of the template, with relatively greater error for lower values than for higher ones. The error however is imperceptible within the range given above. (W. B. SEENS, Research Laboratory, U. S. Steel Corp.)

Bright Annealing of Brass

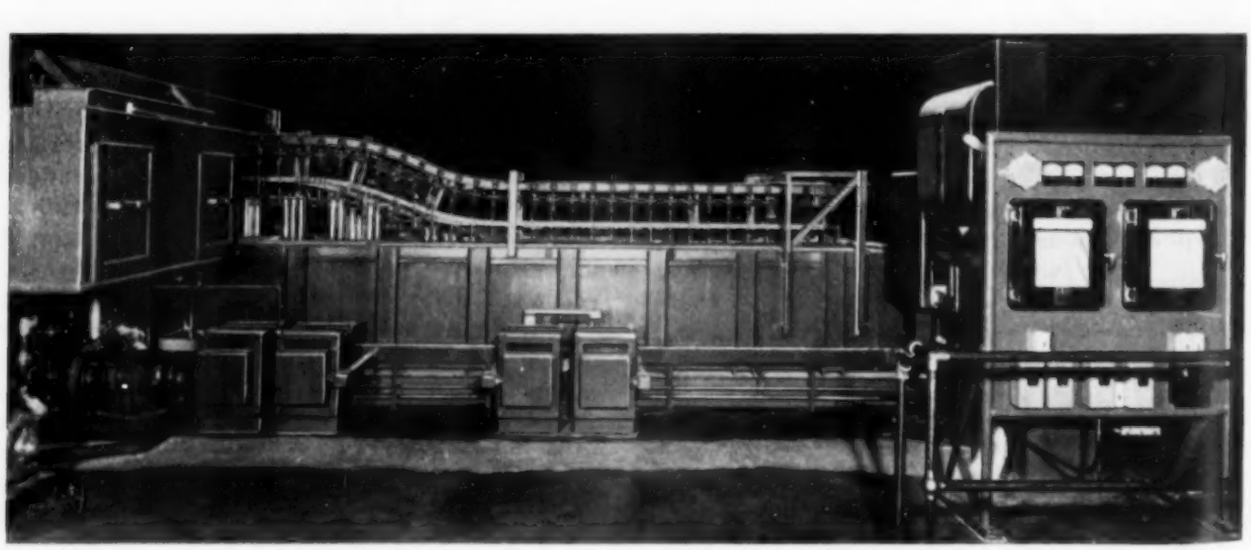
A GOOD DEAL has been published about salt baths for the scale-free heat treatment of steel products, yet so little about similar equipment for handling non-ferrous alloys that a few notes on a Detroit installation are in order. Two furnaces are installed in this plant for the full anneal of brass cartridges, one before and one after the nosing and tapering operation. Capacity of each is 6000 lb. per hr.; speed of the conveying chain is about 60 ft. per min.

As shown in the view below, the furnace contains a single long ceramic pot; the work enters from the left, turns around at the right end of the furnace, is conveyed up and out of the pot into the washer at the left, finally returning to be unloaded at the loading station. Three 75-mm. cases are suspended, mouth down, from each hanger, and a considerable time is provided over the idle end of the furnace for drainage of the adhering salt. Treated cases require no pickling, thus saving one operation required when heat treating in an atmosphere furnace.

Heating current is brought in through bottom electrodes, completely submerged and therefore practically indestructible. Heat is also generated at the bottom of the bath, and thermal currents provide enough movement for thorough uniformity. Temperature variations are held automatically to within $\pm 5°$ F. of the set point (980° F., for example). The ceramic pot also permits the use of inexpensive commercial nitrates for the salt bath. In over two years of operation the furnaces have been shut down at about nine-month intervals for a general clean-up. Drag-out of salt is moderate, and may be completely recovered by evaporating the wash water. (ERNEST F. ELLIOTT, Upton Electric Furnace Division, Commerce Machine Co.)

Distinguishing the Common Aluminum Alloys

METHODS for quick identification of metallic alloys of similar color, luster, hardness and specific gravity — such as presented in many items in Bits and Pieces — require considerable practice and skill. Discrimination of the aluminum alloys is no exception to this statement. The following method utilizes equipment for anodizing the surface (production equipment available in most plants fabricating sheet aluminum parts for the aircraft industry), and the process requires a standard procedure where



Side View of Long Salt Bath (Automatic Controls at Right) for Bright Annealing of Brass Cartridge Cases. Capacity, 6000 lb. per hr.

solution temperature, concentration, time, and current density are all under control, and the surface finish is comparable. A set of samples of known composition, after treatment under these standard conditions, will then form a basis for identification.

The common wrought aluminum alloys, namely, 2S, 3S, 11S, 17S, 24S (occasionally) 52S, 53S and 61S, can be divided into groups:

Group I — Alloys containing 4% or more copper, 11S, 17S, 24S.

Group II — Alloys not containing copper or chromium, 2S, 3S.

Group III — Alloys containing 0.25% chromium, 52S, 53S, 61S.

The alloys in Group I, namely, those containing considerable copper, can be segregated very readily from the others by the fact that when they are immersed in a warm solution of sodium hydroxide, they turn a distinctive black. The black coating, in turn, is readily removed by a quick dip in 50-50 nitric acid. (The 0.25% of copper in 61S of Group III will cause it to darken only to a small extent, and the silicon and manganese in some of the other alloys may produce black spots, but the black from copper is rather distinctive in appearance.) Differences in color are shown up more readily when half the sample is dipped in HNO_3 after the NaOH treatment.

If the metal does not blacken in NaOH, Group III can be distinguished by anodizing. All aluminum alloys containing chromium turn a light, shiny golden color when oxidized. Alloys of Group II are white and lustrous after anodizing.

Once the major separation into groups is made, the next step is to identify the individuals.

Group I — 17S may be separated from 11S (both in heat treated condition) by anodizing; 17ST will be much more shiny.

Group II — Oxide formed on 2S is much brighter than on 3S — previous surface smoothness and cleanliness being comparable.

Group III — Clean alloy 61S turns dull brown in 10% caustic solution due to its copper and silicon content. Separate 52S from 53S by cleaning and dipping in strong alkaline solution; 52S is much less readily attacked. (Vernon H. Patterson, Metallurgist, Bausch & Lomb Optical Co.)

De-Mounting Metallographic Specimens

We wish to point out a useful and interesting application of the usually undesirable stress-corrosion characteristics of materials. It has long been observed in our laboratories that metallographic lucite mounts frequently crack when washed with alcohol or acetone to facilitate drying, particularly with irregular or sharp-cornered specimens. Frequently, it becomes necessary to break specimens out of their mounts without deforming the specimen. We simply apply light pressure to the mount in a vise or a suitable press, pour some acetone on it and within a minute or two the entire mount will be completely shattered and the specimen can be lifted out. (Larry Shiller and Julius Horowitz, Materials Engineers, Washington Navy Yard)

Repairing Aluminum Castings

Carbon arc welding, using a normal metal filler rod (5% silicon, 95% aluminum alloy), has enabled us to salvage a large number of aluminum turret castings that would otherwise be rejected because of porosity or hollow spots. After chipping or grinding out the porous material, that region of the casting is preheated with a torch to 250° F. Preheating simplifies the welding operation and lessens the possibility of cracks by lowering the temperature differential between the point of the weld and the surrounding metal. High heat at the point of weld is also avoided. The use of the carbon electrode with a normal metal welding rod provides a better adhesion between the weld metal and the aluminum casting than when the metal welding rod is used by itself as an electrode.

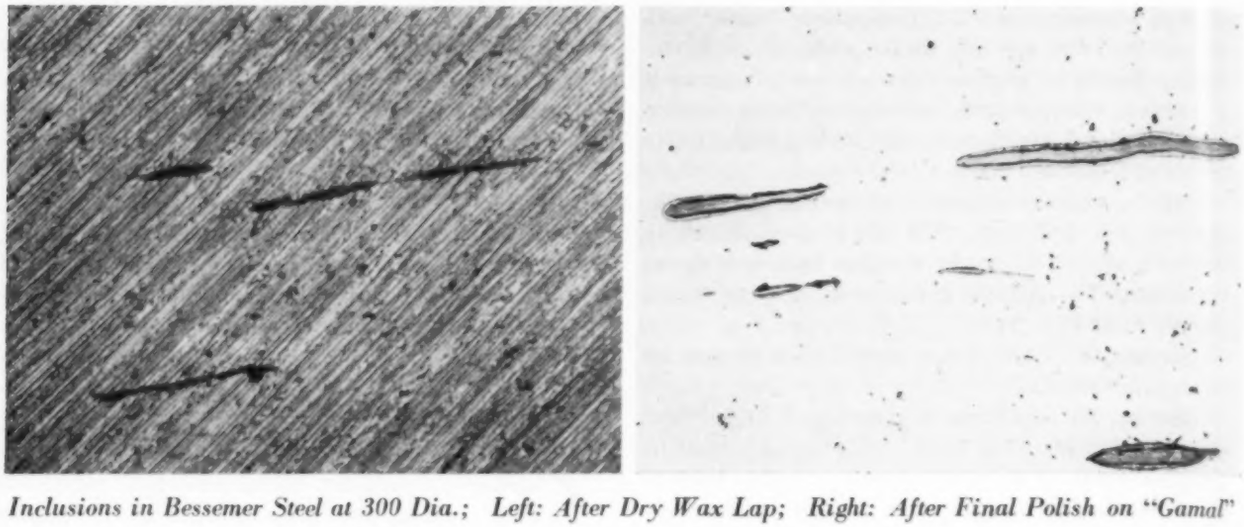
The new method of repairing defective castings is limited in use to low stressed areas. Porosity or hollow spots are determined by X-ray, and following the welding the casting is again X-rayed to insure a perfect bond between weld metal and casting. (Louis Barrett, Tool Design Process Engineer, Glenn L. Martin Co.)

Dry Wax Lapping

A variation in wax lapping technique we have used successfully for a year is to embed the abrasive in the wax and polish the specimen dry.

Sufficient "parowax" to make a volume of 250 cc. is melted, 6 oz. of No. 400 grit alundum is added, the mixture stirred well and poured onto a cloth covered wheel around which a paper dam has been placed. After the wax has solidified, the dam is removed, and the lap given a perfectly flat surface. One way to accomplish this is to place the wheel in a lathe and face it with a cutting tool. The wheel is then ready for use.

A bakelite mounted specimen is first ground on successive grades of No. 2, 1, 0 and 00 metal-



Inclusions in Bessemer Steel at 300 Dia.; Left: After Dry Wax Lap; Right: After Final Polish on "Gamal"

lographic papers. The specimen is then polished on the dry lap by moving it back and forth across the lap while it rotates at about 600 rpm. Polishing should be completed within one minute (after the lap has been "broken in" with one or two specimens). The specimen is now ready for final polishing with levigated alumina or "gamal" without removing the wax film remaining on its surface. If the grinding and lapping operations have been done properly, a specimen can be polished on "gamal" cloth with "gamal" solution in about 5 min.

The left-hand micro printed above shows a sample of bessemer steel after polishing on the dry wax lap. Retention of the non-metallic inclusions after final polishing is shown in the right-hand micro. (CARL J. DAUBER, Metallurgist, Savage Arms Corp.)

Spot Tests for Alloys in Steels

AS AN ADDITION to the data given in Bits and Pieces in past months on rapid chemical methods for distinguishing alloys, the following summary of methods for alloying elements in steel published by Thanheiser and Waterkamp in *Archiv für das Eisenhüttenwesen* in 1941 (page 129) may be useful:

Nickel in Steel — React to completion with one or two drops of 1:1 nitric acid. Neutralize with a slight excess of zinc oxide. Absorb on filter or blotting paper. Add a few drops of standard dimethylglyoxime solution to the paper. A pink stain indicates nickel. The limit of detectability is 0.05%.

Chromium — React to completion with 1:1 nitric acid. Add a drop of water and make alkaline with sodium peroxide. Add one drop of a saturated solution of ammonium oxalate and one drop of a 20% sulphuric acid solution to fix molybdenum. Then add one drop of a solution containing 1% of diphenylcarbazide in 98% alcohol. A violet color indicates chromium. The limit of detectability is 0.20%.

Molybdenum — React to completion with one or two drops of 1:1 nitric acid. Remove reaction products with paper or cloth. React again with one drop of 1:5 sulphuric acid and immerse a piece of filter paper saturated with 10% aqueous solution of potassium ethyl xanthogenate. A red color indicates molybdenum. For molybdenum steels which are difficult to dissolve, react to completion with three drops of 1:1 hydrochloric acid, neutralize with one drop of 20% sodium hydroxide solution, acidify with one drop of 1:5 sulphuric acid and add a few xanthogenate crystals. The limit of detectability is 0.10%.

Vanadium — React to completion with one or two drops of 1:1 nitric acid. Add one drop of phosphoric acid (if titanium is present, add a small crystal of sodium fluoride also) and then one drop of a 3% solution of hydrogen peroxide. A reddish-brown color indicates vanadium. The limit of detectability is 0.10%.

Silicon — React to completion with one or two drops of concentrated hydrochloric acid and add one drop of water. White particles, which rise to the surface in the form of a yellowish foam, indicate silicon. To confirm: Add one drop of 2*N* caustic soda solution, then acidify with one drop of dilute hydrochloric acid and finally add one drop of a solution containing 5 g. of ammonium molybdate, 100 cc. water and 35 cc. of 1:2 nitric acid. A yellow color, which forms slowly, indicates silicon. The limit of detectability is 0.30%.

Manganese — React to completion with one

or two drops of 1:1 nitric acid. Add two drops of 1:1 nitric, two drops of 0.2% solution of silver nitrate and one drop of saturated ammonium persulphate solution (or some small crystals of ammonium persulphate). A reddish-violet color, which forms slowly, indicates manganese. The limit of detectability is 1%.

Aluminum — React to completion with two or three drops of dilute hydrochloric and nitric acids. Make alkaline with potassium hydroxide. Absorb in quinalizarin paper made by soaking filter paper in a solution 10 mg. of quinalizarin and 2 cc. of acetone. A blue to violet color in the paper indicates aluminum. Confirm by exposing the paper in fumes of glacial acetic acid until the blue color changes to red. (Beryllium reacts similarly if more than 0.05% is present.) The limit of detectability is 0.20%.

General Notes — Rather than using the surface of the metal as a spot plate, it is sometimes preferable to absorb the reaction products in a small piece of filter paper and drop the identifying reagents on the paper.

If more than one or two drops of reaction-product solution are desired, the steel may be dissolved electrolytically in dilute acid. (W. A. Mudge, Asst. Director of Technical Service, International Nickel Co.)

Rapid Estimation of Grain Size in Magnesium Castings

Since the common method of preparing cast magnesium alloys for grain size determination is rather a lengthy one, this shortened method will be a time saver:

Preparation — Specimens for microscopic examination may be prepared in 4 to 5 min. by a technique adapted from A. L. Schaeffler on page 285 of *Metal Progress* for August 1944. Rough grinding is done on a No. 2 emery paper; finish grinding on a wax lap using a solution of 100 cc. of water, 4 cc. of liquid soap, and 10 g. of No. 100 alundum; and final polishing on a "gamal" lap using a solution of Linde "B" polishing powder (similar to No. 3 alumina) and water.

Etching — The normal procedure of preparing specimens for grain size determinations, unless the metallographer has had considerable experience with magnesium alloys, is to solution heat treat the sample before microscopic examination. This is necessarily a lengthy procedure.

By etching with a solution of 10% tartaric acid in water the grain structure of cast magnesium alloys is revealed in the as-cast condition, thus eliminating solution heat treatment. This etchant is a development of one mentioned by H. Vosskühler on page 40 of "The Technology of Magnesium and Its Alloys".

Etching may be done by immersion in the solution or by simply pouring some of the solution over the specimen, followed by washing under running water and drying in a stream of warm air. The etching time is from 5 to 15 sec. Too long time causes staining and pitting. On etching some alloys a black film may form; this may be removed while washing the specimen by rubbing gently with the finger or with moistened absorbent cotton.

Besides being satisfactory for as-cast magnesium alloys this etchant also very readily attacks the grain boundaries of the material after solution heat treatment. (J. P. Ogilvie, Metallurgist, Canadian Bureau of Mines)

Spotting Soft Spots

We have found the following etching procedure very useful in our laboratory for finding soft spots on parts which have been carburized and hardened, then finish ground. We can locate areas as little as 5 to 8 points Rockwell softer than the rest of the area. Hardness differentials of a higher degree give a stronger indication, and it is such areas, of course, that we are more concerned with. The procedure is as follows:

Clean the parts carefully in benzol or some equally high solvent after drying thoroughly with a soft clean cloth, then submerge for 5 to 7 min. in 1% nital. (3% nital may be used providing the time is shortened to take care of the speed of the etch.) After etching and washing, buff the part lightly on a felt polishing wheel, using levigated alumina in water, until a metallic luster is just returned to the metal. Parts having irregular shapes may be buffed by hand with the felt. After the part has been buffed or polished, it should be washed and dried carefully, then submerged again in the 1% nital for 50 to 70 sec., then removed, washed and dried. Soft areas will now be outlined and identified by excessive darkening. The extent of the darkening indicates the degree of softness.

By a study of the shape and distribution of such areas, combined with a microstructure study, we can usually determine the probable cause of the defect. We have found this procedure useful on such parts as oil and water pump shafts, idler gear pins, rocker arm shafts, camshafts, and numerous Tocco hardened parts. (L. P. Begley, Metallurgist, General Motors Corp., GMC Truck & Coach Division)

Pressure Welding

Metallurgical Aspects of High Quality Pressure Welded Joints for Landing Gear — Part I — Influence of Oxygen

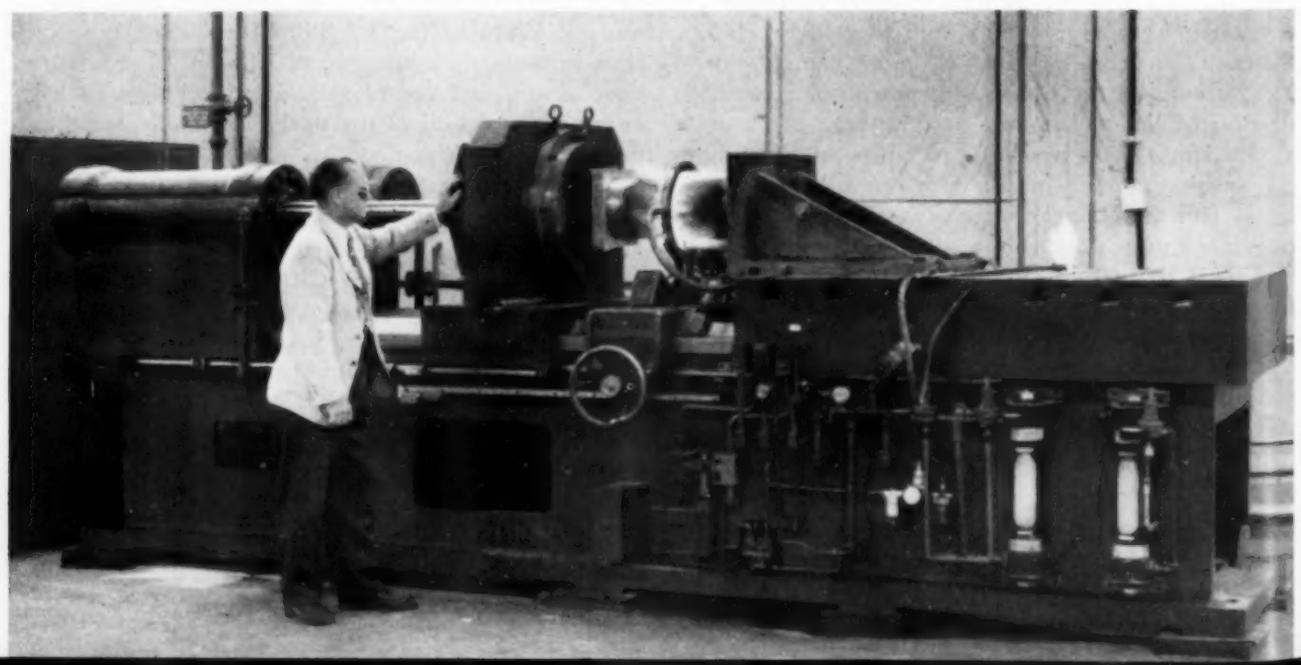
By Leslie Fine, Charles H. Maak and Anthony R. Ozanich
Metallurgical Laboratory, Menasco Mfg. Co., Burbank, Cal.

BY OXY-ACETYLENE pressure welding, joints of 100% strength in bending can be made with a high degree of consistency in low alloy, medium carbon steels, heat treated to 180,000 to 200,000 psi. tensile strength. A. B. Kinzel said in his Adams Lecture before the American Welding Society in 1944 that pressure welded joints have been made in a large range of carbon and alloy steels as well as some non-ferrous metals, but the experimental work conducted by the authors has been largely with medium carbon, low alloy steels such as are used in aircraft landing gear. (The pressure welds at Menasco Mfg. Co. are made with what is known as the "Uniweld Process" and hereafter will be referred to under the trade name.) Since uniwelds in critical joints of aircraft landing gear assemblies are heat treated after welding, all bend specimens used for testing quality are heat treated to 180,000 to 200,000 psi. tensile strength before testing. Such specimens are welded tubes supported on ends and loaded in bending to failure in the center by a saddle.

This process of welding has been found particularly well suited for landing gear because the consistently high quality joints necessary for such application can be made. Economies are achieved because parts difficult or impractical to forge and machine in one piece can be fabricated from simple sub-assemblies into one unit possessing physical properties equal to an equivalent part made in one piece. Uniwelding also lends itself to economies in quantity production because holding fixtures for rapid alignment of parts permit a high rate of production and reduction of costs.

Uniwelding is accomplished by butting together under pressure two machined faces of parts to be welded, at the same time heating the area of the weld plane until sufficient upsetting takes place. The essentials are intimate contact of surfaces to be welded, heat, pressure, and exclusion of air or any material that might cause physical or chemical discontinuity between the butting weld faces. Bonding is the cohesion of metal at the weld plane due to atomic attraction effected by

Fig. 1 — The 16-In. Uniweld Machine at Menasco Mfg. Co. in Operation



intimate contact of weld surfaces. In a practical sense, however, hot working (upsetting) is the agency by which intimate contact is effected in this process. Hot working also serves to break down inhibiting films on the weld faces and cause recrystallization across the weld plane. Further re-orientation of grains is produced by the transformation that takes place in low alloy steel.

Essentials of the Equipment

The equipment required is essentially a press of required capacity equipped with fixtures for holding in alignment the parts to be welded, an oxy-acetylene heating head, and a device to measure and control the amount of "gather" (shortening of the parts due to upsetting). Figure 1 illustrates a well designed hydraulic uniwelding machine in which the movable carriage at left is axially loaded by two hydraulic pistons moving in a plane through its center line. Such axial loading minimizes misalignment or angularity of the component parts.

The principal requirement of the heating head is that it produce a high temperature throughout the weld interface at a rate suited to the particular section. The linear heat gradient, both axially and radially, must also be considered so that weld faces do not open up because of differential thermal expansion. The heating head usually oscillates laterally or angularly so as to distribute the flame from each orifice over an appropriate area; this not only transfers heat efficiently but also prevents overheating of the metal beneath flame tips.

The heating head shown in Fig. 2 has orifices equally spaced and drilled radially in the inner surface and is designed for welding tubing. Other accessory control equipment consists of oxygen and acetylene flow-meters, regulators and pressure gages. Extent of upsetting can be effectively controlled by a limit switch to turn off the hydraulic pressure and fuel gas to the heating head simultaneously after the required amount of gather has taken place.

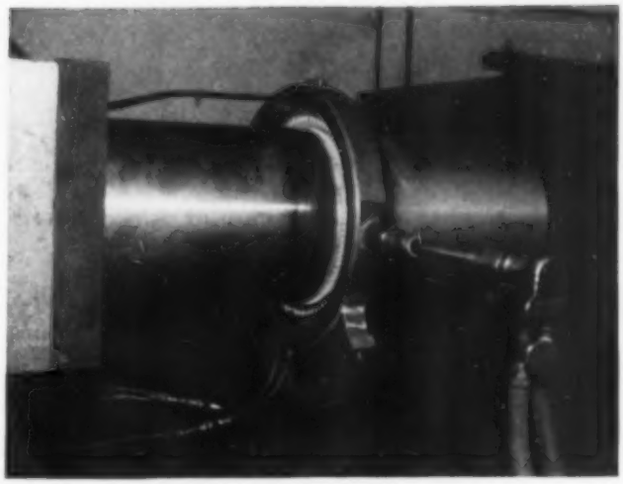


Fig. 2 — Close-Up of Heating Head in Operation

In practice, parts are machined with a good finish on the weld faces and located in the weld machine solidly by fixtures providing accurate alignment. All controls are set and the upsetting pressure is applied before the heating head is lit. The heat, being concentrated at the weld plane, limits upsetting to a relatively small volume at the weld plane until the gather-control mechanism shuts off the heat and pressure. The welding cycle is complete and the part can be removed immediately from the machine and a new weld started. Welding time ranges from a few seconds to several minutes, depending on the wall thickness of the weld. An average time for a tube with ¼ in. wall is about 2 min. Figure 3 shows parts before welding and the completed weld. Figure 2

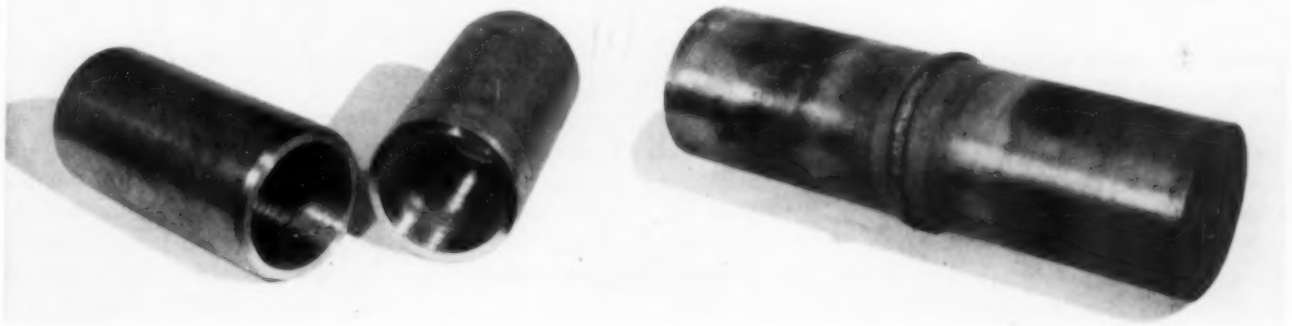


Fig. 3 — Parts Prior to Welding and the Joint Immediately After Being Removed From the Machine. The chamfer on the exterior is designed to secure a desired balance between inner and outer upsets

A Note on the Data Sheet

ALL combinations of tempering time and tempering temperature that lie on the same hardness difference line in the chart making up the Data Sheet on page 352-B will produce the same hardness for a given steel and a given structure before tempering. (Note, however, that the chart has not been tested for high alloy steels.)

Example: A high carbon steel tempered 10 hr. at 880° F. has a certain hardness. What tempering temperature would give this same hardness in 2 hr.?

Solution: In the chart, 10 hr. at 880° F. falls at *A*, on "Hardness Differential Line 60". This line crosses 2 hr. at *B*, which is at 940° F.

For steels without large amounts of carbide-forming elements, the difference in the hardness produced by two tempering treatments is approximately equal to the differential between the Rockwell C numbers given on the chart for the two treatments. This is not true, however, for hardnesses less than C-20 Rockwell or within three Rockwell C numbers of the hardness before tempering.

Example: A 1095 steel tempered 11 hr. at 1100° F. has a hardness of C-34 as determined experimentally. What would be the approximate hardness if it were tempered 4 hr. at 900° F.?

Solution: 1 hr. at 1100° F. (Point *C*) falls on line 65.5; 4 hr. at 900° F. (Point *D*) falls on line 59.5; the differential is 65.5 — 59.5 = 6. Hardness 34 + 6 = Rockwell C-40.

shows the weld immediately before the heating head is shut off.

On every set of experimental uniwelds made, metallurgical samples are always welded. Size of the internal and external upsets, alignment of the specimens, and contours of the flow lines can be noted by macroetching. Refer to Fig. 4. Since flow lines do not match on each side of the joint, the plane of juncture can easily be located. Note

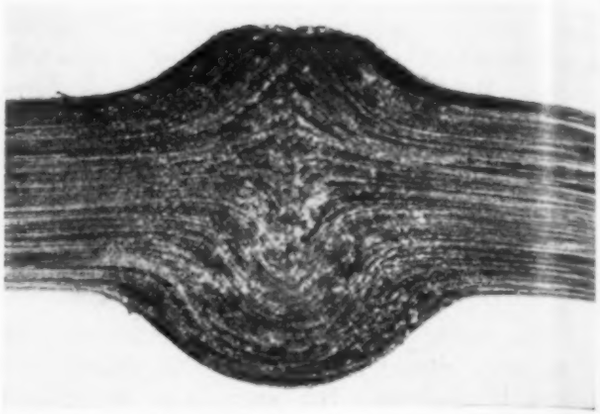


Fig. 4 — Macrograph (at 4 Diameters) of Uniweld, Sectioned and Etched in Hot Hydrochloric Acid

that the inside diameter upsets (below) are larger than the outside diameter upsets; occasionally small fissures occur on the internal upsets and the larger upset makes it an easy matter to machine off such a fissure. No fissures are ever located on the outside upsets of approved welds; however, due to the close proximity of the flame, a small amount (usually not over 0.040 in.) of metal is "burned" and it is therefore desirable to remove part of the external upset as well.

At first the only microscopic examination that was used was after a nital etch of the plane of juncture (weld plane). However, this yielded practically no information; both good welds and poor welds appeared similar.

See Fig. 5 of a specimen which, after notching and breaking with a sharp hammer blow, revealed a flat fracture on the weld plane. It was impossible to correlate these undesirable flat fractures with any appearance in the nital-etched specimens, but as pointed out in the article by Leslie Fine in last month's *Metal Progress* the presence of oxygen in flat fractures was suspected. After the alkaline chromate solution described in

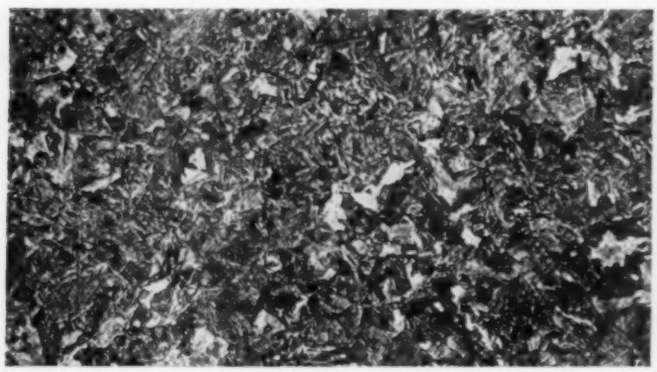


Fig. 5 — Cross-Section Through Weld Plane of a Poor Weld Which Broke With Flat Fracture. Nital etch; 200×

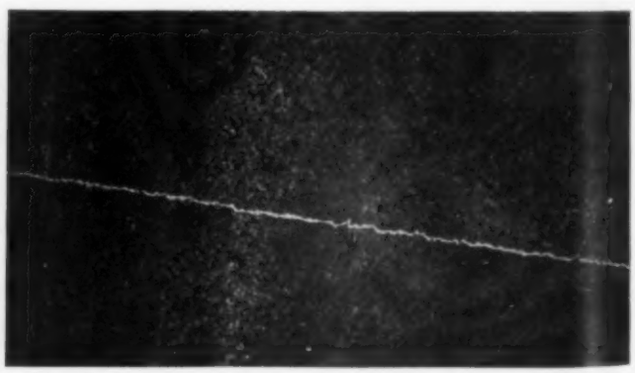
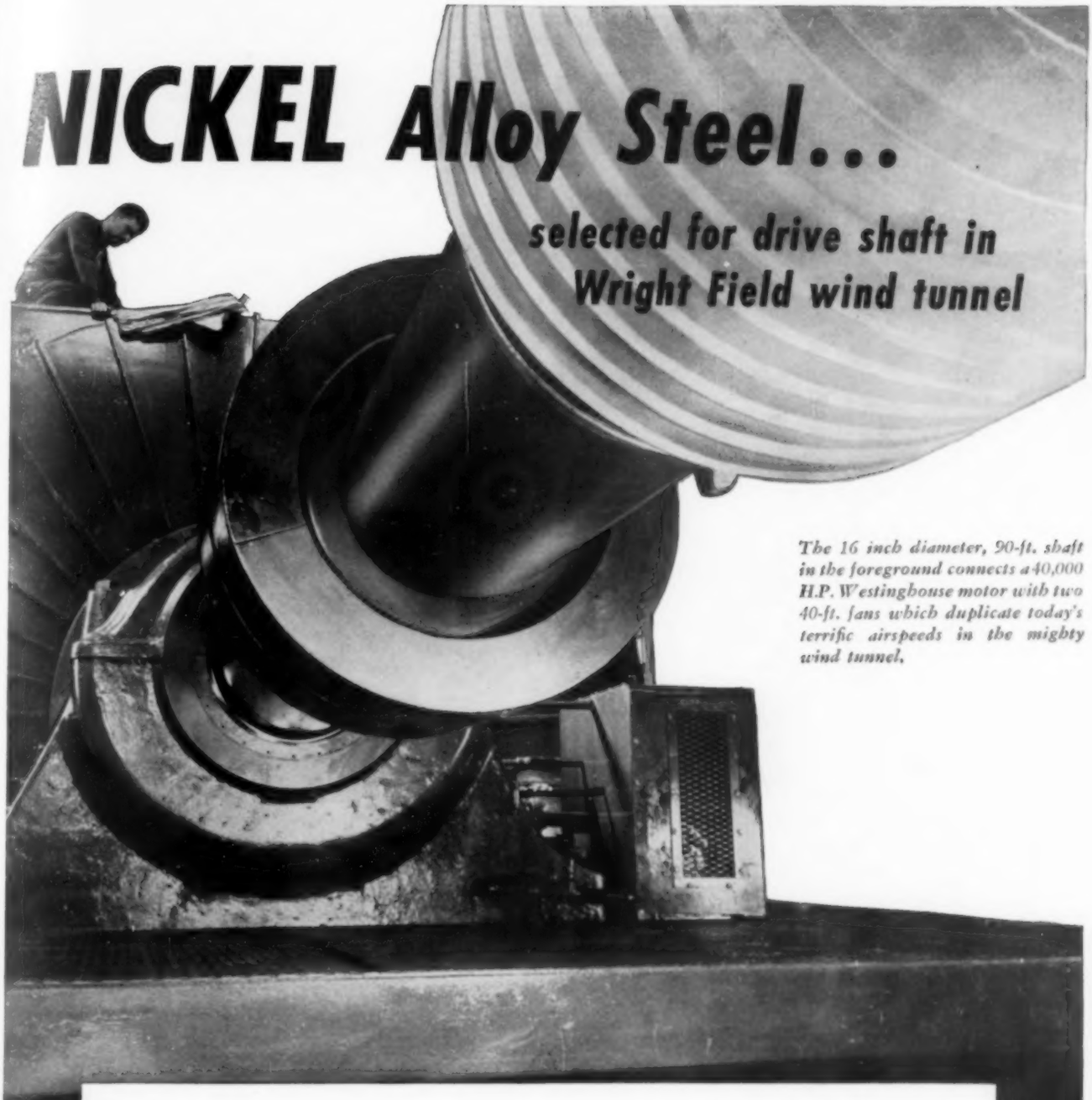


Fig. 6 — The Same Area, Re-Etched With Alkaline Chromate, Showing Thin Streak of Oxygenated Metal

NICKEL Alloy Steel...

selected for drive shaft in Wright Field wind tunnel



The 16 inch diameter, 90-ft. shaft in the foreground connects a 40,000 H.P. Westinghouse motor with two 40-ft. fans which duplicate today's terrific airspeeds in the mighty wind tunnel.

The high mechanical properties required for this large drive shaft were specified by Westinghouse Electric Co., Inc., suppliers of the wind tunnel motor and auxiliary equipment.

To meet the specifications, a Nickel-molybdenum steel was selected.

Significant are test results on bars from prolongations of the forgings, after normalizing and tempering:—

Ultimate tensile strength	117,500 p.s.i.
Yield Point	90,500 p.s.i.
Elongation in 2"	20.0 %
Reduction in Area	55.4 %

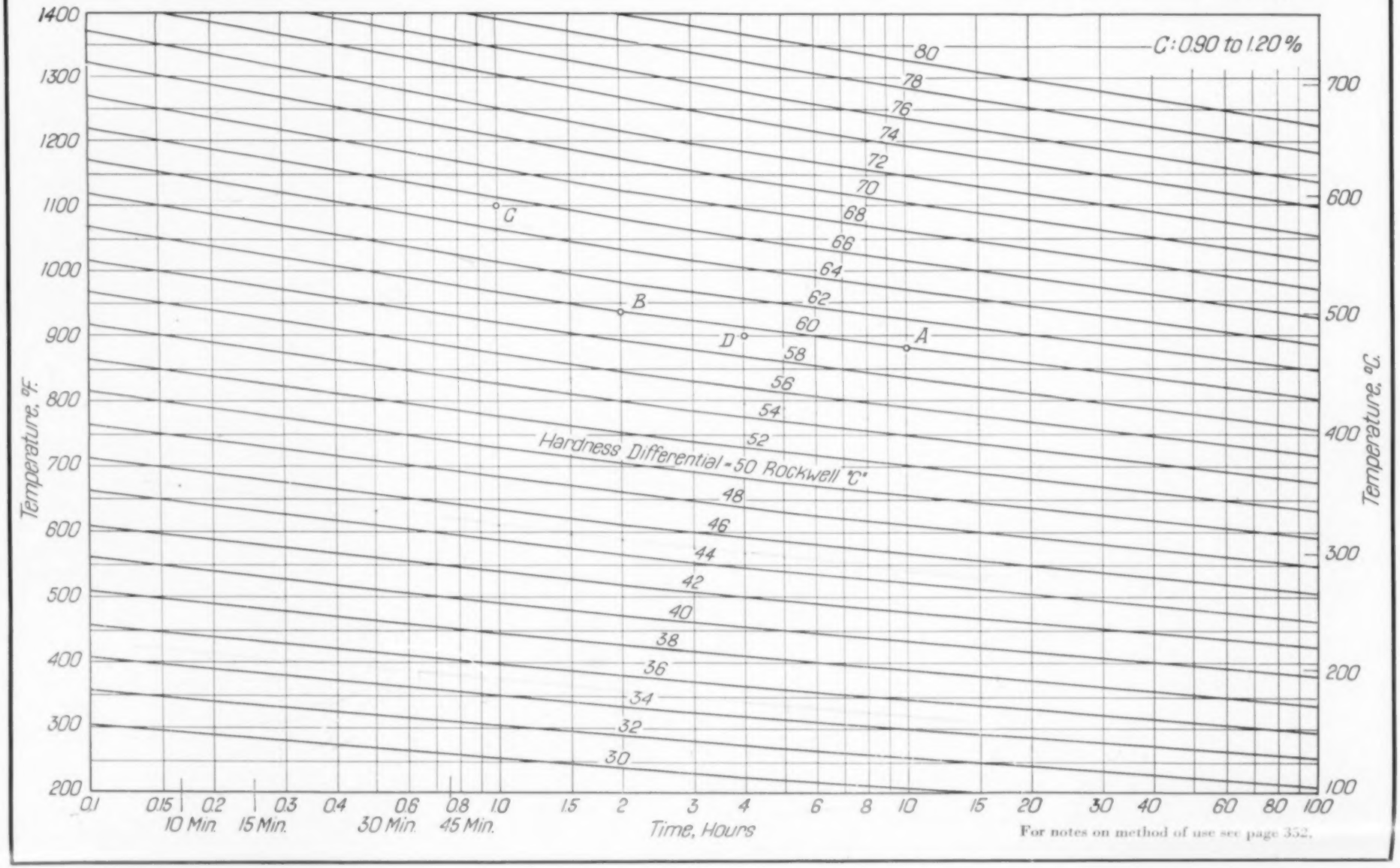
We invite inquiries on the uses and selection of Nickel alloy steels, and other Nickel alloys.

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N. Y.

Time-Temperature Relations in Tempering High Carbon Steels

By J. H. Hollomon and L. D. Jaffe

From A. I. M. E. *Transactions*, 1945, *Vol. 162, p. 223*



For notes on method of use see page 352.

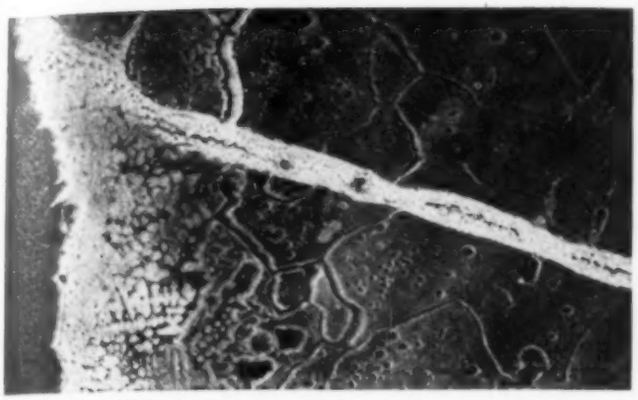


Fig. 7 — Pressure Weld Between Rough, Saw-Cut Faces Permitting Much Oxygen to Be Absorbed. Alkaline chromate etch; 100×. Note oxygenated surface (left edge of micro) and grain boundaries of overheated metal

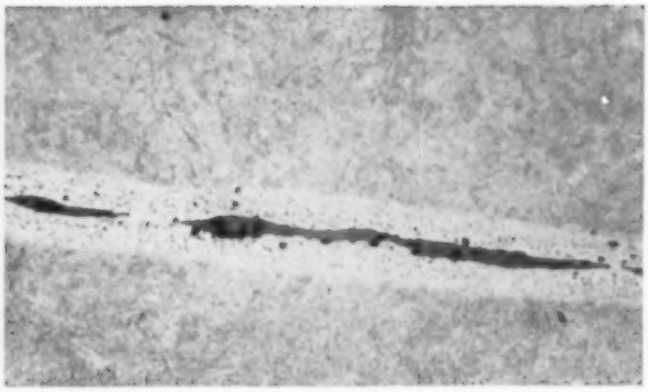


Fig. 8 — Deeper Portion of Weld Similar to Fig. 7. Lightly etched with alkaline chromate; 500×. Inclusions are iron oxide

that article was developed, it was tried on uniwelds with remarkably successful results. Compare the section through the weld plane of a poor uniweld etched in nital (Fig. 5) and the identical area etched in alkaline chromate solution (Fig. 6). The alkaline chromate etch very clearly shows the thin oxygen segregation at the weld plane.

To develop an extreme example of this condition, abutting specimens were prepared with saw-cut faces to give as much air (oxygen) access to the weld face as possible. Figure 7 shows the relatively thick layers of oxygenated metal along the weld plane as well as at the heated surface. Figure 8 shows another weld prepared in the same manner, after etching lightly in an alkaline chromate solution. The inclusions shown in the plane of the weld were analyzed microscopically according to the chemical methods described in the Metals Handbook, 1939 edition, page 741, and were found to be iron oxides.

After it was found that uniwelds having a white zone present at the weld plane possessed inferior physical properties we tried to diffuse this oxygen segregation away from the weld plane by heat treatment, but found that the rate of diffusion of oxygen was quite slow even at temperatures as high as 2300° F.

For example Fig. 9 shows, at left, an as-welded coupon cut from a uniweld made with saw-cut faces. Next is the same after soaking 13 hr. at 1800° F. Alongside are sections held at 2300° F. for 30 min., 3 hr., 8 hr., respectively. Even the last did not completely diffuse the oxides remaining as occasional light dots with black centers along the weld plane running in an upwardly sloping direction. At temperatures within a practical heat treatment range, the diffusion rate was too slow to be considered for industrial application. The conclusion was that the only workable way to get good welds was to get them without a "white zone" to begin with.

These observations on the rate of diffusion of oxides in steel indicate that the theoretical rate presented by Mr. Kinzel in his Adams Lecture is not borne out experimentally. He presented a mathematical argument to establish a rate that would completely diffuse an oxide film approxi-

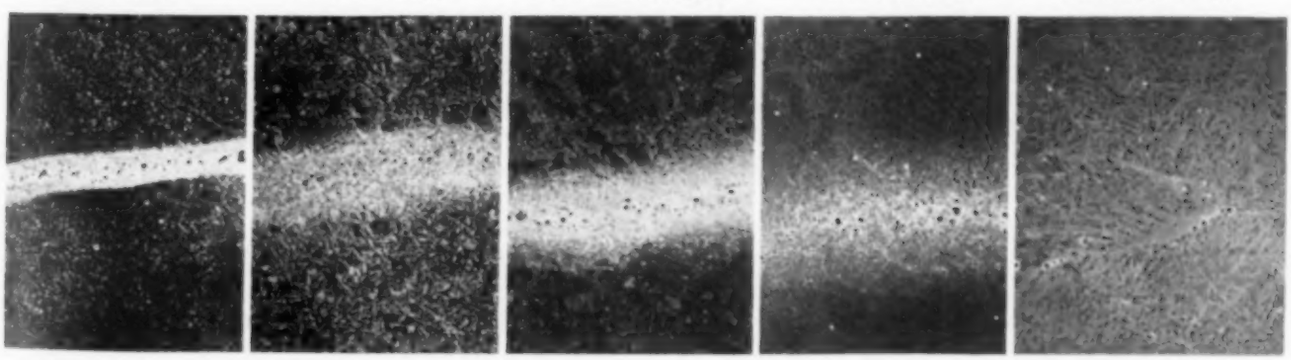


Fig. 9 — Oxygen-Rich Zone Like Fig. 7, As-Welded and After Various Diffusion Heat Treatments. 200×

Metal Progress Data Sheet, February 1946, Page 353-B

mately 0.1 mm. (0.004 in.) thick in approximately 30 min. at 1000° C. (1830° F.). The affected zone shown in Fig. 9 was only 0.001 in. thick (one-quarter the amount cited by Kinzel) yet it could not be completely diffused in 8 hr. at 2300° F.

Mechanism of Oxygen Diffusion

At this point the authors present their concept of the mechanism of oxygen diffusion in steel and show how that mechanism can be applied to uniwelding.

When steel is exposed to air at a high temperature, diffusion of oxygen into the steel occurs. On evidence so far accumulated with low alloy, medium carbon steels, the reactions appear to be as follows: Oxygen is soluble in hot steel in measurable amounts. Thus diffusion takes place without any precipitation until saturation occurs. With increased oxygen input the zone of diffusion deepens and some precipitation occurs in the first-formed areas. This precipitation appears to consist of small particles of FeO. With further oxygen input these small FeO particles grow and it appears that the surrounding metal simultaneously becomes lower in dissolved oxygen or oxide. Possibly the particles serve as nuclei for the additional precipitation of FeO from solution. Cooling to room temperature would precipitate more FeO. If the diffusion proceeds still deeper, the particles of FeO which are the largest, being those nearest the source of oxygen and also the ones acted on first and having the most time for coalescence and growth, react further with oxygen to form Fe_3O_4.

On this basis it would appear reasonable to expect the inclusions nearest the surface to be mixtures of FeO and Fe_3O_4 and of large size. The FeO particles become progressively smaller with increased distance from the surface until an area is reached in which only a saturated solution of dissolved oxygen or oxides exists; deeper is oxygen-free base metal. The demarcation between the area of saturated oxygen or oxides in iron and the base metal appears to be sharp and in line with the known facts that the oxygen gradient is very steep from outside to inside.

Applying this theory to the white zone of Fig. 9, it can be visualized as the joining of two of these surface reactions in which the surfaces have had little time to react with oxygen and usually contain only small dotted inclusions (rarely some larger FeO inclusions). If the oxygen in such a weld be diffused at high temperature new conditions are introduced since there is no outside source of oxygen. As the sample is reheated some of the small particles begin to re-dissolve in the steel, and the dissolved oxygen or oxide at the weld plane begins to diffuse from a locale of high to one of lower concentration. As the concentration of oxygen in solution becomes lower and lower at the weld plane, more of the FeO inclusions dissolve and the process continues until all of the particles dissolve and disappear from the weld plane. If the reaction is stopped at some intermediate point one actually finds fewer "dotted" inclusions near the weld plane but a wider zone containing enough oxygen to show clearly in the alkaline chromate etch. Some of the dotted inclusions also re-precipitate at some distance from the weld plane. (This precipitation is probably due to super-saturation upon cooling to room temperature.) Some of the larger

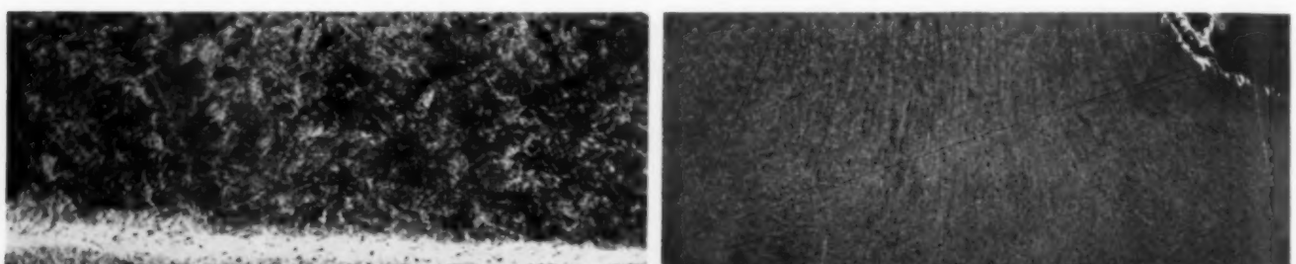


Fig. 10 and 11 — Flash Welds in Tubing With 3/16 and 1/32-In. Walls (Low Alloy, Medium Carbon Steel) Etched With Alkaline Chromate. 100×. The 3/16-in. wall, when etched with nital, did not reveal the weld plane

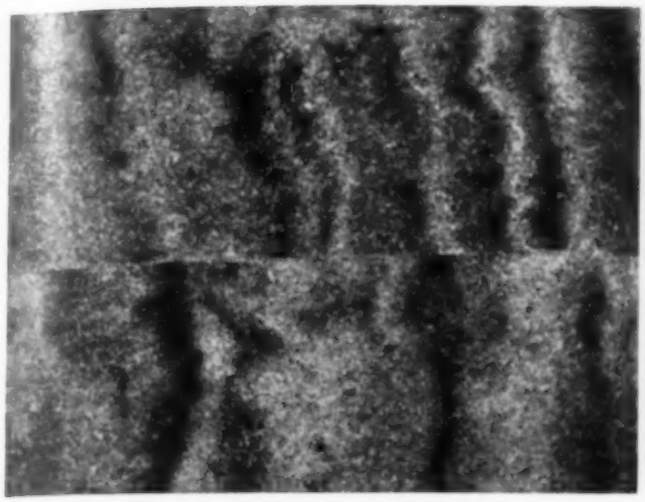


Fig. 12 — Average Quality Uniweld in NE 8630. Alkaline chromate etch; 100×

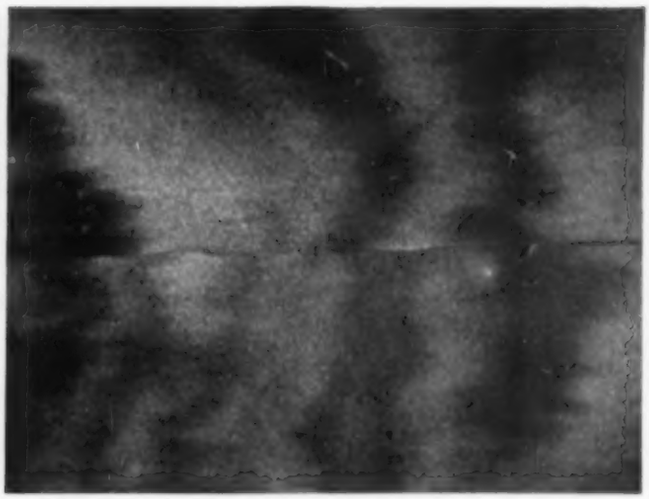


Fig. 13 — Average Quality Uniweld in S.A.E. 4340, Heat Treated to 180,000 to 200,000-Psi. Tensile Strength

inclusions near the weld plane disappear but others appear to change in composition to Fe_3O_4. This latter observation does not follow the theory, and as yet cannot be fitted into the picture. It appears, however, that if the reaction be allowed to continue for a sufficient length of time all of the particles — including those which appear to be oxidizing to Fe_3O_4 at the intermediate steps — would dissolve and disappear.

From the emphasis that has been placed on oxygen, one should not receive the impression that oxygen is the only factor affecting weld quality. Bonding is also a fundamental requirement, but in the welding of low alloy, medium carbon steels in production, no difficulties have ever been encountered due to poor bonding.

In flash welding, where the faces are not in contact during heating and actually reach the melting temperature before being upset, good bonding readily occurs. However, oxidation of the two faces is inherent in the process. In this way, flash welding is similar to a metallic arc weld made with a bare electrode. The flash welder cannot exclude oxygen from the plane of the weld as does the pressure welder, but rather must depend on the force of upsetting to push out all of the oxidized metal that is formed. This oxidized metal is probably not only molten but plastic and therefore it is very difficult to eliminate all of it. Hence, the flash welder is limited in the size of high quality welds it can make. For example, Fig. 10 and 11 show, respectively, as-welded flash welds, etched in alkaline chromate solution, made from $\frac{3}{16}$ and $\frac{1}{32}$-in. wall tubing of low alloy, medium carbon steel. On the basis of the alkaline chromate etch, this latter weld appears to be of better quality than the one in the heavier walls. Due to the thinness of the wall, the section shown in Fig. 11 actually was air quenched; the structure at the weld plane is slightly tempered martensite, and as noted in Mr. Fine's article last month, it would darken slightly in the nital etch due to its higher oxygen content.

In summing up the microscopic evaluation of uniwelds, Fig. 12 and 13 show the actual quality now secured at Menasco Mfg. Co., as revealed by the alkaline chromate etch. Figure 14 shows an internal fissure sometimes encountered. Such fissures when they do occur are very shallow and far less in depth than the amount of metal in the internal upset, and are readily removed by machining off part of the upset.

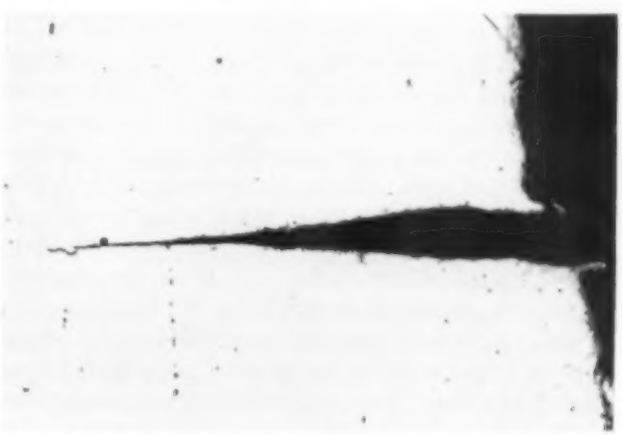


Fig. 14 — Large Fissure on Inside Diameter of Uniweld in Tubing; 100×. Cross-section polished, not etched. The base of the fissure which appears to follow an intergranular pattern is the portion that has propagated during heat treatment. Fissure is actually about 0.035 in. deep and is machined off by boring bar

Editorial

Critical Points

By The Editor

TO GRAND RAPIDS and talked to a highly attentive audience gathered by the ⊕ Chapter about atomic energy and some of its foreseeable influences on American life. In competition, in the same hotel, was a much more numerous gathering of local politicos who listened to a congressman, reported by the newspapers next morning as highly critical of the domestic policies of the Truman regime (yes, he was a Republican). So was somewhat depressed that so much to-do was being made over the misfeasances of minor bureaucrats when the very earth is trembling, and remembered an amazingly prophetic play, "Wings Over Europe", written in 1928 by two Englishmen, ROBERT NICHOLS and MAURICE BROWNE, and recently revived by the Cleveland Play House. In this play a young scientist tells the British Cabinet in its meeting room at 10 Downing Street that he has discovered the "secret" of the atom, a statement wholly incomprehensible to them even when he explains that an ability to transmute a table-top into a slab of gold makes their money system meaningless, the ability to blast the whole of London makes the King's army and navy meaningless, and the ability to generate unlimited power makes the current economic system meaningless. He asks them as practical politicians, men skilled in the art of government, to devise a new society for the common man harmonious with man's new and revolutionary power over nature. All they can think of doing (after all their posing pretenses are sloughed away) is to murder the discoverer, thus thinking they can kill the discovery, only to find out after the crime is committed that other physicists, working independently, have discovered the same secret, now secret no more.

Wings over Europe

AN OLD FRIEND, a civilian engineer, U.S.N., reminds me that the Navy goes on, war or no war, and machinists will continue to cut off the sound surface, the best part of a pressure casting, whether of steel, gun metal or leaded red brass, and thus convert a good piece into a leaker. And so was discussing the problem of reclaiming leaky castings with ALBERT DEMMLER, long with Vanadium Corp. of America but now director of metallurgy and research of Campbell, Wyant & Cannon Foundry Co. Of course a good foundryman regards the reclamation of leaky castings as a salvage operation that must be approved by both producer and customer, but my naval friend asks "What would you do if leakage developed past a piston and the officer responsible has only a few hours remaining to stop the leaks and undock the ship?" DEMMLER said that a thermosetting plastic like bakelite is not only highly effective against leakers if injected into the water jackets and internal passages, but it flows over and fixes the last traces of core sand remaining behind, and does not cause anti-freeze solutions to foam — a common fault of the inorganic salts often used. Impregnation of "solid" castings by way of a drill hole like an oil line is also favored by some metallurgists. There are doubtless other effective methods, some most useful on the original casting, some effective even for emergency repairs with the minimum of equipment and without moving the part from its position. Complete information on such processes would be most welcome to W. H. HAMMOND at Hunters Point Drydocks, U.S.N., San Francisco 24 (and also by the less well informed Editor of *Metal Progress*).

Emergency repairs to leaky castings

GOT an entirely new respect for industrial, truck, and tractor engines after a day at the Muskegon plant of Continental Motors Corp., where E. C. GINN, vice-president, outlined the activities in considerable detail. Here are made no less than 80 different engines, ranging from a single cylinder, air-cooled, ⅝-hp. job for a farm lighting unit to a 320-hp. brute for hauling Uncle Sam's artillery over rough country. Experience with radial, air-cooled tank engines and small

aircraft engines for trainers and civilian planes has convinced the Continental staff that the pre-war bus, truck, and highway tractor engines can be profitably refined in design and the weight per horsepower greatly reduced — fuel economy and general reliability being correspondingly improved. Extension of this idea to its logical conclusion has produced engines that are made of heat treated or alloy steels, cast irons and aluminum alloys (with the exception of a few low stressed parts) even to ordinary studs and bolts made strong enough to defy a repairman with an extra long wrench handle. TOM SNYDER, chief metallurgist, says that the metallurgical control is unusually searching. Nothing is released for manufacture until incoming inspection is complete and the lot accepted. Insistence on quality raw materials costs money, not only for the inspection but frequently in an extra first cost, but he points out that, in his experience, these costs have always been recovered in lower scrap losses during manufacture and fewer rejects at the end. Once good material is accepted, it gets a second scrutiny after heat treatment, and a third after final finishing. WAINE THOMAS, assistant chief engineer, said that improved materials, improved alloys and improved designs have enabled the engines to run at constantly increasing speeds and heavier working stresses. High speed engines need the highest quality in reciprocating parts, and hence it is not surprising to find connecting rods inspected with magnaflux, and design-checked with "stresscoat" to insure against overloaded regions, special attention given to the condition of fillets, and the crankshaft assembly carefully balanced and counterweighted. This would be expected in an aircraft engine but hardly in one for a heavy truck. Nevertheless, such attention to all details produces 200-hp. truck engines that cruise at 2200 rpm. and run 65 miles per hour (3000 rpm. max.) and operate economically 300,000 miles between major overhauls. Application of these general principles, together with refinements in design generally — in keeping with knowledge about combustion published in the literature and gained in the 15 experimental test cells where engine modifications are under constant study — has effected changes such as the following: One of the pre-war L-head engines developed 127 hp. under test conditions; the present engine with the same cylinder displacement but with overhead valves develops 163 hp. under test conditions (fuel of the same grade). THOMAS says that a considerable increase in efficiency resulted from a change in valve location from L-head design to valve-in-head design. Another instance of a more powerful engine: Pre-war engines of the 750 to 800-cu.in. displacement class operated at approximately 2100 rpm. and developed from 170 to 180 hp., whereas one of Continental's latest developments in the same displacement class develops around 280 hp. at 2800 rpm. Apparently the more brains and quality material you put into one of these things, the more horsepower you get out.

Better (not heavier) truck engines

HAVE RECEIVED some letters from the Editor's son in France recounting the grim condition of that unfortunate country as to food, fuel and clothing. He has sent the names and addresses of many metallurgists and technicians who sadly need our help, at least to the extent of a monthly parcel of food. Any member of the ⊕ who desires to perform such an act of mercy should write the Editor for the name and address of a French brother. Shipping directions and suggestions about contents of boxes are also available.

Food for French metallurgists

TO WASHINGTON, and glad to find that human rabbit-hutch somewhat less congested, judging by the population in the Union Station and the relative ease of finding a taxi and a meal, and more glad to know that a competent staff is cataloging and abstracting all the government's secret, classified, and restricted documents as they become disclosed, declassified, and unrestricted, and even more glad to know that by President TRUMAN's order this opening of the records is proceeding rapidly (LOUIS JORDAN of War Metallurgy Committee assuring me that all but a half-dozen of its reports will be public property within a few weeks). Any ASMember who is interested in, say, magnesium castings, should write to The Superintendent of Documents, Government Printing Office, Washington, D.C., asking to be placed on the mailing list of the weekly publication "Bibliography of Scientific and Industrial Reports Distributed by the Office of the Publication Board". This periodical will show the titles, brief abstracts, location of the original document, and cost of a reproduction of all reports on, say, magnesium castings, as they become available.

Government technical information

UNABLE TO REFUSE a recent invitation by the Cleveland Chapter to give the Coffee Talk preceding D. K. CRAMPTON's comprehensive address on copper and brass seamless tubing. Posing as an old-timer from the copper industry (which, by

Einstein on the Atomic Bomb

Extracts (by permission) from an article by Albert Einstein in The Atlantic Monthly *for November, 1945*

THE RELEASE of atomic energy has not created a new problem. It has merely made more urgent the necessity of solving an existing one. As long as there are sovereign nations possessing great power, war is inevitable. That fact was true before the atomic bomb was made. What has been changed is the destructiveness of war.

I do not believe that civilization will be wiped out in a war fought with the atomic bomb. Perhaps two-thirds of the people of the earth might be killed, but enough men capable of thinking, and enough books, would be left to start again, and civilization could be restored.

I do not believe that the secret of the bomb should be given to the United Nations Organization. The secret of the bomb should be committed to a World Government, and the United States should immediately announce its readiness to give it to a World Government. This government should be founded by the United States, the Soviet Union, and Great Britain — the only three powers with great military strength. All three of them should commit to this World Government all of their military strength. The fact that there are only three nations with great military power should make it easier rather than harder to establish such a government.

Since the United States and Great Britain have the secret of the atomic bomb and the Soviet Union does not, they should invite the Soviet Union to prepare and present the first draft of a Constitution for the proposed World Government. That action should help to dispel the distrust which the Russians already feel because the bomb is being kept a secret, chiefly to prevent their having it.

After the three great powers have drafted a Constitution and adopted it, the smaller nations should be invited to join the World Government. They should be free to stay out; and though they would be perfectly secure in staying out, I am sure they would wish to join. But the Big Three should go ahead and organize the World Government whether the smaller nations join or not.

The World Government would have power over all military matters and need have only one further power — the power to intervene in countries where a minority is oppressing a majority, creating the kind of instability that leads to war.

The establishment of the World Government must not have to wait until the same conditions of freedom are to be found in all three of the great powers. It is not necessary, in establishing a world organization with a monopoly of military authority, to change the structure of the three great powers. It would be for the individuals who draft the Constitution to devise ways for the different structures to be fitted together for collaboration.

I appreciate that there are persons who favor a gradual approach to World Government even though they approve of it as the ultimate objective. The trouble about taking little steps, one at a time, in the hope of reaching that ultimate goal is that while they are being taken, we continue to keep the bomb secret without making our reason convincing to those who do not have the secret. That of itself creates fear and suspicion, with the consequence that the relations of rival sovereignties deteriorate dangerously. We have not time to spend in this way. If war is to be averted, it must be done quickly.

We shall not have the secret very long. Other countries which have the materials and men can apply them to the work of developing atomic power if they care to do so.

Since I do not foresee that atomic energy is to be a great boon for a long time, I have to say that for the present it is a menace. Perhaps it is well that it should be. It may intimidate the human race into bringing order into its international affairs, which, without the pressure of fear, it would not do.

Copper—no poor man's industry

the way, like becoming dean of your profession, can be achieved simply by living long enough, although that in itself is something of a trick) the Editor told the audience about some mines and smelters in Colorado, Montana and Utah he knew between 1900 and 1915, first warning them that time serves as a magnifying glass to enlarge the importance of all youthful recollections. America's pyrotechnic copper industry since 1875 has had more sound engineering lavished on the mines and smelters than skull-duggery in the stock market, and it is well, for otherwise the copper industry could hardly exist. Like the history of a mine, which exhausts its bonanzas in a hurry and then ekes a precarious existence for a few more years scavenging the leavings, so also is the history of our nation as a copper producer. We have entered the scavenging stage, for at present more than one-third of our new copper comes from "ores" (waste rock in 1900) containing close to 1% copper. Such low grade rock can only be treated profitably in great tonnages, and that means that the small mine and smelter has all but vanished — now 80% of American copper is produced by three rich

The Atomic Bomb and World Government

Extracts (by permission) from an article by Sumner Welles in The Atlantic Monthly *for January, 1946*

THE ATOMIC BOMB has touched all peoples with hysteria. It has moved the idealists to rush to the conclusion that all the great achievements represented by the agreement of 51 nations to establish the United Nations Organization must immediately be scrapped. They are convinced that a fresh start must be made without delay.

No World Government of the character envisaged by Professor Einstein could function unless it possessed the power to exercise complete control over the armaments of each constituent state, and unless every nation was willing to open up every inch of its territory and every one of its laboratories and factories to a continuing international inspection. Nor could it function unless the government of each participating country was equally willing to submit to the scrutiny of the authorities of the World Government every one of its governmental processes, including its conduct of foreign and internal affairs and of finance.

It surely requires no demonstration that any such requisite as that would wholly destroy the present Soviet system. We have every reason to be confident that unless the Soviet Union could dominate the proposed World Government as to preclude the possibility of any weakening of its own control of Russian foreign and domestic policy, it would not participate in that government.

There is another aspect of Professor Einstein's proposal which fills me with amazement. He declares that his World Government should have "the power to intervene in countries where a minority is oppressing a majority, creating the kind of instability that leads to war". But any such intervention upon the part of his World Government, in the internal affairs of independent peoples, for the sole purpose of imposing upon them a standardized form of government or a particular brand of political philosophy, would subject the nations of the world to a dictatorship exercised by the Big Three, with all other peoples as abject serfs. No free world can be founded upon such a concept.

The Republic of Uruguay has recently made public a proposal that the American republics consider the possibility of joint action on the part of all of them when, by common agreement, any American Government has abrogated the rights of its citizens to determine their own destinies and to enjoy the individual freedoms to which they are entitled, and has thereby violated its treaty obligations and endangered the highest interests of all of the peoples of the New World.

There are 21 independent republics in the American family of nations. It is therefore altogether improbable that joint action could ever be undertaken in order to further the selfish interests of any one major power or to pave the way for aggression or unilateral domination.

If, therefore, in the United Nations Organization the power to correct any infringement of the liberty of individuals were to rest exclusively in the hands of the Assembly, where the smaller nations possess a great majority, the danger that such intervention might be exercised in the exclusive interest of the three major powers, or of any one of them, could be avoided.

What Professor Einstein seems to me to overlook, in his insistence that moving slowly means war, is that from the standpoint of existing facts it is an utter impossibility to do anything else than move slowly until the mutual fears and suspicions existing between so many nations of the world have been ended. How can these fears and suspicions be ended until and unless all nations, and particularly the Big Three, work together within the United Nations Organization and thus little by little discover by actual proof that there exist no valid reasons and no basic causes for their mutual fears and suspicions?

corporations. We used to export one-third the copper we mined, but we are now barely able to meet our own requirements, which, by the way, seem to be headed for stabilization at about one million tons per year. The industrialization and electrification of the rest of the world, now coming on rapidly, must be taken care of by new mines in Canada, Chile, Rhodesia and the Congo. Fortunately, copper does not rust and seldom wears out, and is valuable enough to be gleaned by the junk man. Recoveries of so-called secondary metal from demolition scrap are currently equal to about half the new copper gained from American mines. This proportion of secondary metal is bound to increase — eventually the whole world will reach a point where mining of new copper will be everywhere more expensive than the reclamation of old and no-more-useful objects made of that remarkable metal.

STIMULATED, as occasionally, by a Hollywood production, this time a glowing invitation to attend the unveiling of a new house in that progressive village. With proper perspective, it is erected on a $75,000 lot (or so the pamphlet states) and is designed for living in the electronic age. The kitchen is an electrician's delight and obviously gives full sway to the satanic ability of any

maid to foul up such simple things as irons, toasters and vacuums. Wiring to each room is engineered so that there is an outlet for radio, both broadcast and f.m., television, and Musac; flowerlike transparencies are flooded with colored light, and the general illumination can be high enough for reading, or softened to the misty glow of our better night clubs. The carport (garage to you) houses both automobile and helicopter. Heartening, indeed, is one item proving that the designers have not lost touch completely with a more Spartan youth: Know that the bathroom is equipped with a magazine rack! — large enough for a Montgomery Ward catalog, let us hope..... Let this serious comment on gadgeteering be closed by quoting with heartfelt approval from a recent mailing piece of Lindberg Steel Treating Co.: "It is our personal hope that in tomorrow's Utopia we will have in our house a can opener that works, even if it sets us back 50¢."

A house for the electronic age

APOLOGIES are due to two publications, since *Metal Progress* is guilty of unwittingly publishing material without proper credit — something that offends us when others steal our articles. Last May we printed an article entitled "The Effect of Tolerances on Measurements" by Sir Charles Darwin. It was sent us by an English correspondent without any hint that it was the Edward Williams Lecture presented to the Institute of British Foundrymen. Again — the long table on corrosion resistance of the stainless steels in wrought and cast form published as an appendix to Carl Zapffe's article in last October's issue was exclusively derived from *Chemical & Metallurgical Engineering*....Private apologies have been made by letter; this is public flagellation.

Confession of error

OF COURSE the American Society for Metals exists because of its ability to get correct information into the hands of those who need it, and we are therefore not surprised by such requests as "Please send me all the information you have on heat treatment". However, all of us in the National Office are baffled by the brief note that came in only the other day. It read:

Information, please

"Please send me any information you may possess regarding the various items you have information on."

Those who doubt that such a letter could possibly have been written by anyone except a Japanese school boy will receive a photostatic copy of it on receipt of 25¢ to help pay for postage and packing.

Tapping a 30-Ton Aluminum Furnace at Bohn Aluminum and Brass Corp., Detroit

Calibration of Pit Furnaces for Airplane Propellers

By Carl A. Liedholm
Chief Engineering Metallurgist, Curtiss-Wright Corp., Propeller Division, Caldwell, N. J.

IT IS TRUE that metallurgical manufacturing procedures or engineering materials giving reasonably satisfactory results can be developed by hit-and-miss experimentation, but rarely if ever will such methods allow the available equipment to operate at its maximum capacity and yet within the zone of safety — nor are these methods likely to be of real help in selecting materials that lend themselves to the most economical production. For instance, ignorance of the exact heating characteristics of a furnace means waste of production and money either through excessive heating times or through inadequate heating times and re-heats. Incomplete knowledge of the quenching characteristics of a steel will result either in the acceptance of heats which fail to harden satisfactorily, or heats which are prone to develop quenching cracks or are difficult to weld or machine. Lack of knowledge concerning the behavior of steel during slow cooling, or isothermal transformation preceded by slow cooling, might mean the difference between proper and improper post-heating of weldments, and hence between economical welding production and a wasteful proportion of manufacturing scrap.

It follows from these considerations that specific and accurate metallurgical information is one of the essential requirements of economical manufacturing. Metallurgical research is comparatively expensive, and this obligates those responsible to confine the activities of industrial laboratories to the development of data that can be applied as directly as possible to improve the product, reduce manufacturing scrap, or increase the efficiency of metallurgical manufacturing processes. To attain these objectives, the metallurgist may frequently be forced into fields of study which appear purely academic, but nevertheless hold the key which opens the door leading from assumptions to dependable information. In other instances, he may reach the goal by simple and obvious experimental methods.

To further the application of metallurgical research to the manufacture of its products, Curtiss-Wright Corp., Propeller Division, organized a central metallurgical laboratory in 1942, devoted exclusively to the development of technical information required for proper engineering of those metallurgical manufacturing operations, materials, and processes which are essential to airplane propeller manufacture. Some of the major studies of this laboratory have concerned the heat treatment of hollow steel propeller blades. A by-product of these studies has been two contributions to *Metal Progress* for January and November 1944, which discussed the transformation of alloy steels during continuous cooling and its bearing on the die quenching of hollow steel propeller blades, as well as five data sheets plotting such transformations in X-4130, 4315, 4330, 6135 and 8630 steels.

The present contribution and its sequel will deal with simple studies undertaken to safeguard blade quality in conformity with specification requirements. A secondary purpose was to eliminate re-heats and heat treating scrap. These studies fall in two categories distinctly different in kind and objective. The first deals with routine determinations of the heating characteristics of furnaces for different loads and operating conditions and is part of the requirements of an engineering specification entitled "Final Heat Treating Specification for Hollow Steel Propeller Blades". The second is part of a general long-range investigation undertaken to find reliable methods of heat treating propeller blades without scaling and decarburization, and to eliminate or "correct" any decarburization (introduced by previous heating

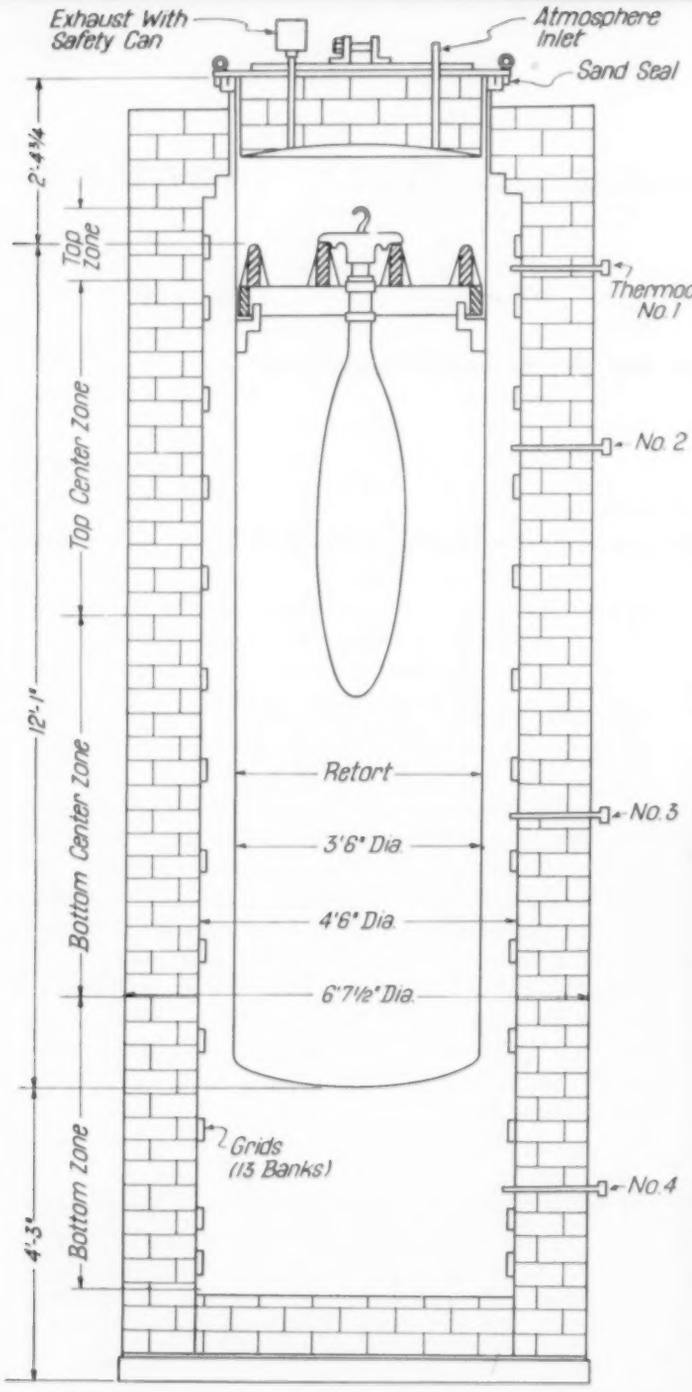


Fig. 1 (Above) — General Drawing of General Electric Pit Furnace With Normalizing Retort, Cover and Small Blade

operations) by "carbon restoration" or "controlled recarburization". It is probable that atmosphere calibrations of this type may become part of engineering specifications — see for example the notable series of articles in *Metal Progress* between August 1943 and January 1945 by Floyd E. Harris on carburizing and other reactions between hot steel and special atmospheres.

This contribution will begin with a brief description of the furnaces and the atmosphere generating equipment, and then deal separately with the simple instrumentations and methods used in the temperature and atmosphere calibrations, and include a brief summary of the results of each study.

Choice of Equipments — The data reported herein were obtained from furnaces specially designed for the production of comparatively small

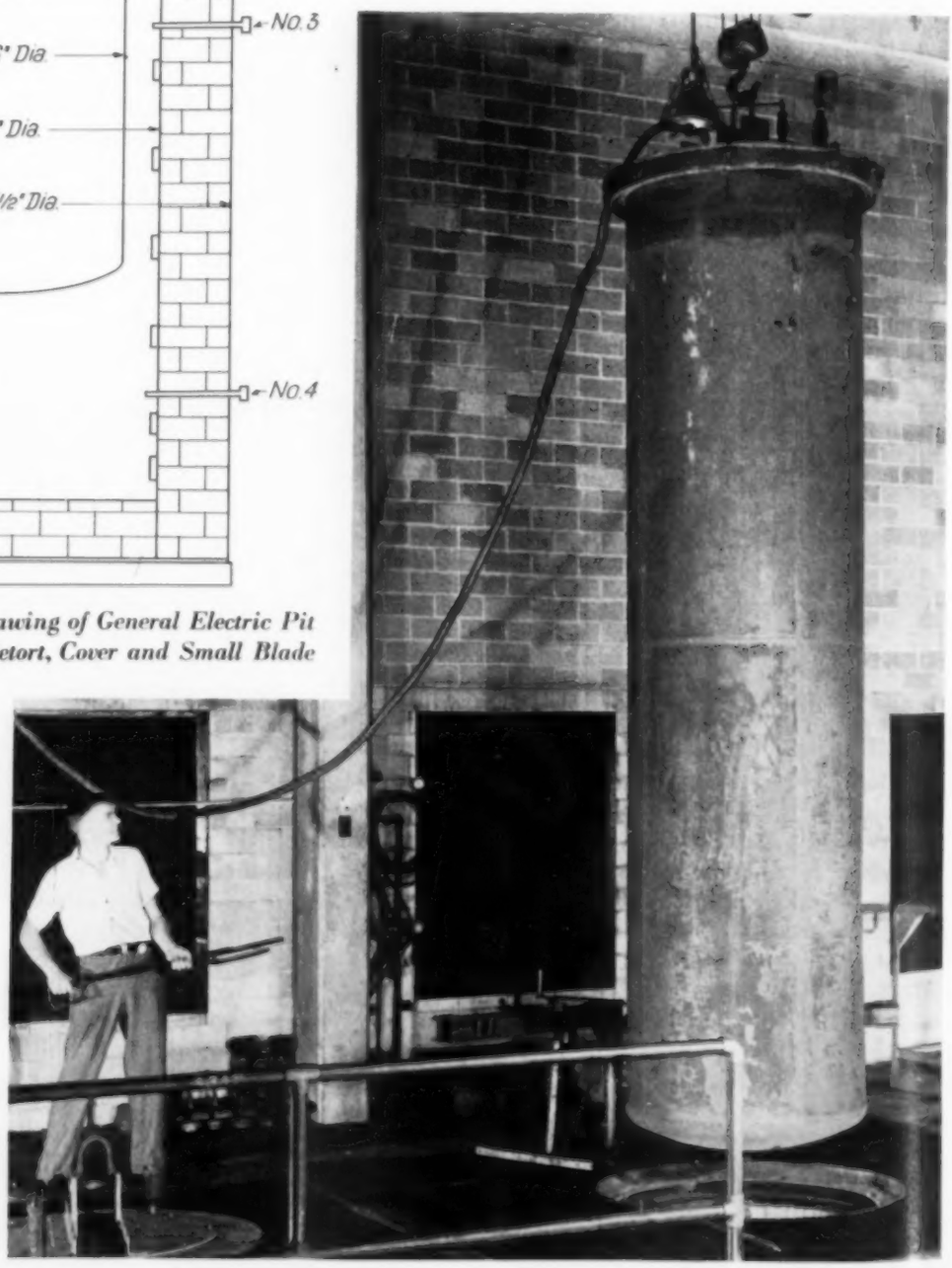


Fig. 2 — Loaded Normalizing Retort About to Be Lowered Into Furnace

lots of experimental blade models. This choice of equipment was due to the following reasons: Although temperature surveys had been made for all our production furnaces, uninhibited experimentation was impossible on furnaces which were required to operate continuously on production loads. On the other hand the experimental furnace equipment could be shut down for alterations whenever desired.

Two furnaces were used in both phases of the experimental work, one of which was for high temperature (normalizing and hardening) and the other for low temperature operations (stress relieving and tempering). The small number of experimental blades made it desirable to have each furnace built for more than one operation; however, both of them were constructed so a protective atmosphere could be positively maintained.

High Temperature Furnace

The high temperature pit furnace shown in Fig. 1 was designed and built by the General Electric Co. It is a cylindrical refractory pit elements fastened to the inside brick wall. Two 14.5-ft. deep retorts, of 3.5-ft. inside diameter and 127-cu.ft. volume, are available. One retort is used for normalizing and the other for hardening. The retort for normalizing carries supporting beams suspended by hangers fastened to the top edge and capable of carrying four blades of medium size. The retort's heavy metal cover rests in a sand seal and is clamped to the retort with eye bolts and carries the entire weight. This retort is moved by a hoist from the furnace to one of the two cooling pits, thus permitting it to be loaded, purged with protective atmosphere and unloaded at temperatures below the scaling temperature in the cooling pit. Figure 2 shows the charging of the retort into the furnace.

The hardening retort, although of the same size as the normalizing retort, is intended to heat only one blade at a time. A special blade hanger (with inlets to deliver atmosphere and pressure gas *inside* the hollow steel blade) enters the retort through a central hole in the split cover. The cover carries the weight of hanger and blade as shown in Fig. 3. The cover is raised and lowered by compressed air but swung open by hand to charge or remove a blade. A baffle under the cover prevents excessively rapid loss of atmosphere while the retort is open. The baffle has an oblong slit cut in it at the center, just large enough to pass the blade. The retort is transferred from a cooling pit into the furnace and is brought to full hardening temperature and purged with atmosphere before it is charged.

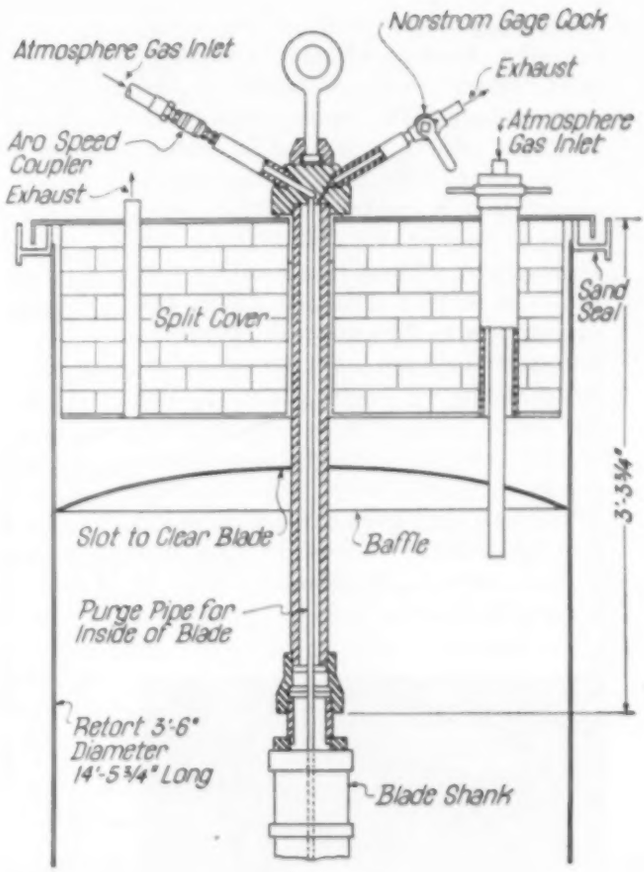


Fig. 3 — Loading Arrangements for Hardening Propeller Blade With Controlled Atmosphere Both Within and Outside of Blade

Temperature is controlled by four Leeds and Northrup strip chart controllers actuated by chromel-alumel thermocouples located in the top, top center, bottom center, and bottom heating zones, as shown in Fig. 1. Thermocouples No. 2, 3 and 4 each control one circuit of four banks of heating elements, and enter the furnace centrally with respect to the circuits they control; the top thermocouple, No. 1, controls a circuit consisting of a single bank of elements and enters the furnace just beneath the elements in this bank.

Low Temperature Furnace — The low and high temperature furnaces are essentially of the same type and built by the same firm. They have approximately the same depth, but the low temperature furnace is 6 in. larger in internal diameter and is heated by 12 banks of elements arranged in three zones of four each. There are available three retorts of 4-ft. inside diameter, designed to be moved by crane between the furnace and any of the three cooling pits. In these retorts heating and cooling can be done under a protective atmosphere. One retort, whose volume

is 141 cu.ft., is for medium and small propeller blades, whereas two 181-cu.ft. retorts can accommodate the largest blades. The heavy metal cover on these retorts is similar in design to the cover of the normalizing retort, except that it contains a 22-in. centrifugal blower for circulating the atmosphere. (There is one such cover for each retort.) The fan forces the atmosphere to flow down in the annular space between an internal cylindrical baffle of 3.5-ft. diameter and the retort wall, then up through the retort. The maximum furnace capacity is seven blades of medium size, either suspended the same way as for normalizing or hung by the tips (shank down). Its general design is shown in Fig. 4.

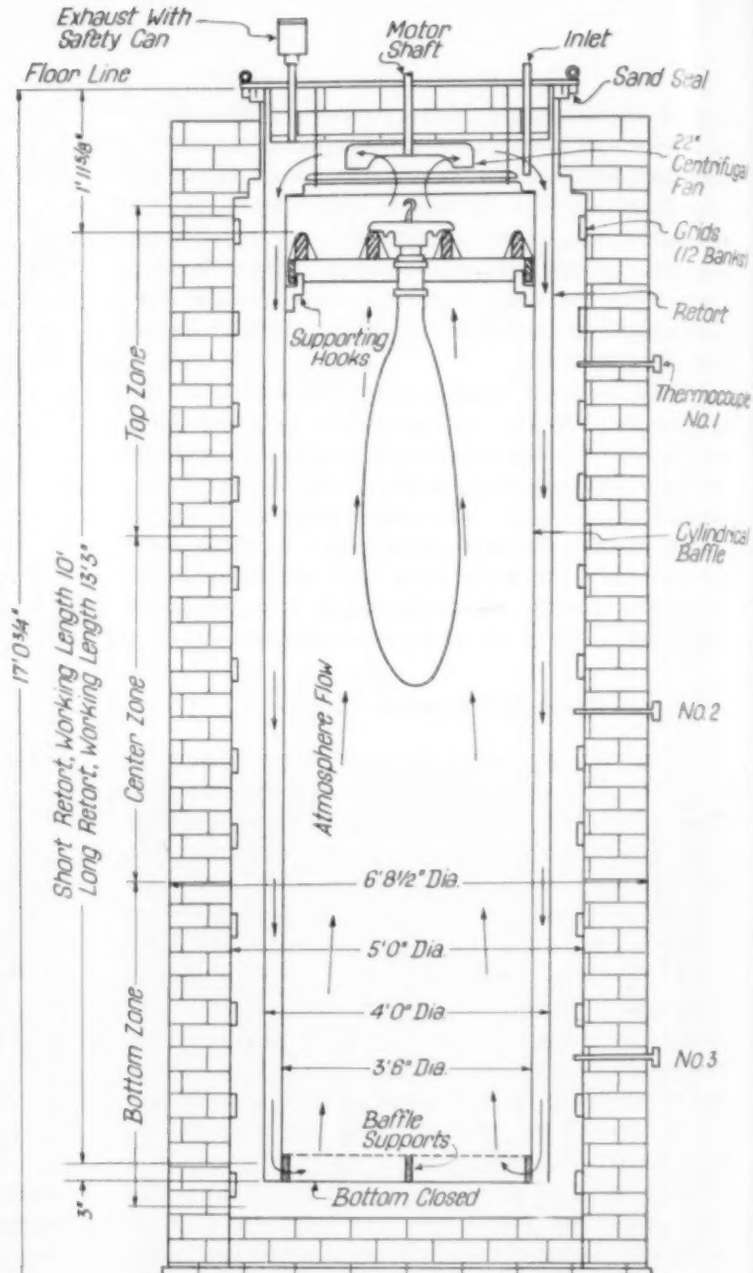


Fig. 4 (Above) — Low Temperature Pit Furnace for Stress Relieving or for Tempering Under Controlled Conditions

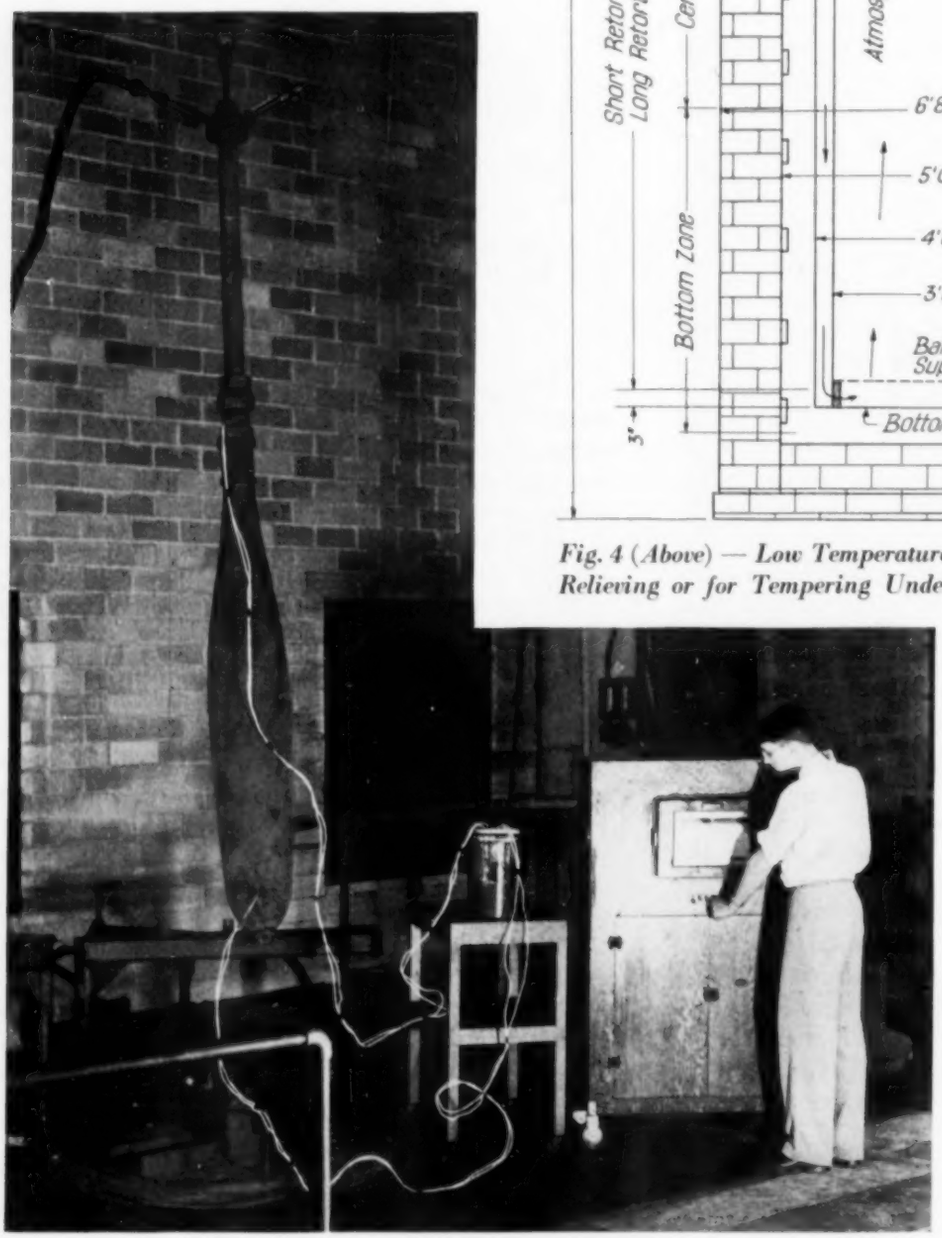


Fig. 5 — Thermocouples Peened Into Small Holes at Thickest and Thinnest Section of Test Blade Before Entering the Hardening Furnace

There are three furnace control thermocouples and instruments; iron-constantan thermocouples are used, but otherwise the instrumentation is similar to that of the hardening furnace.

Atmosphere Generators — Both the furnaces described above are equipped with General Electric atmosphere converters, originally lined for low air-gas ratios but later relined to operate on high ratios (after preliminary surveys had indicated the desirability of this change). The capacity of the present high temperature furnace generator is 1000 cu.ft. per hr.; that of the generator for the low temperature furnace is double. Since, with this generating equipment, the normalizing retort cannot be purged simultaneously with the hardening operation, the smaller generator should be replaced with one of greater output, in order to utilize the full furnace capacity.

The high temperature furnace generator has the following auxiliary equipment: Intercooler, a water scrubber, a hydrogen sulphide absorber, a CO_2 absorber using monoethanolamine, a refrigerator which cools the pre-combusted atmosphere to about 4° C., and an activated alumina unit capable of drying the atmosphere to a dewpoint of −60 to −70° C. The atmosphere generator for the low temperature furnace has no auxiliary equipment except an intercooler and, hence, delivers an atmosphere relatively high in CO_2 and H_2O. Both generators are operated with producer gas.

Temperature Survey Instrumentation — The heat treating specification referred to previously requires the determination of the heating characteristics of a furnace before it is released for use in production. Such surveys must be performed with the furnace operating on full load, and the production operation must conform with the procedure recommended by the survey report.

For batch type furnaces the survey must include loadings where propeller blades are in all equivalent positions given by the symmetry of the furnace and load distribution. Another specification requirement is that the control blades shall have thermocouple beads attached by welding (or by peening into a small hole) to the outside of the tip and inside of the shank at about the 9-in. station. (The purpose is to cover the fastest as well as the slowest heating and cooling cycle existing in a blade in any position in the furnace.) Figure 5 shows a blade wired for surveying the hardening retort in the high temperature furnace, and Fig. 6, the load and survey couple wires leading from a charge in a low temperature retort.

Individual temperature cycles in these experiments were determined with a six-point Tagliabue universal temperature recording potentiometer, mounted in a wooden cabinet equipped with casters for easy transportation. A large thermos jar was used for cold junctions. All blades used in the survey work were wired with 18-gage chromel-alumel thermocouples.

Prior to each survey, the Micromax instruments were checked against a Brown portable potentiometer, and the furnace thermocouples compared to a calibrated standard couple placed in the furnace alongside the couple being checked.

Fig. 6 — View Into Loaded Retort in Low Temperature Furnace, Showing Thermocouple Leads From Critical Locations

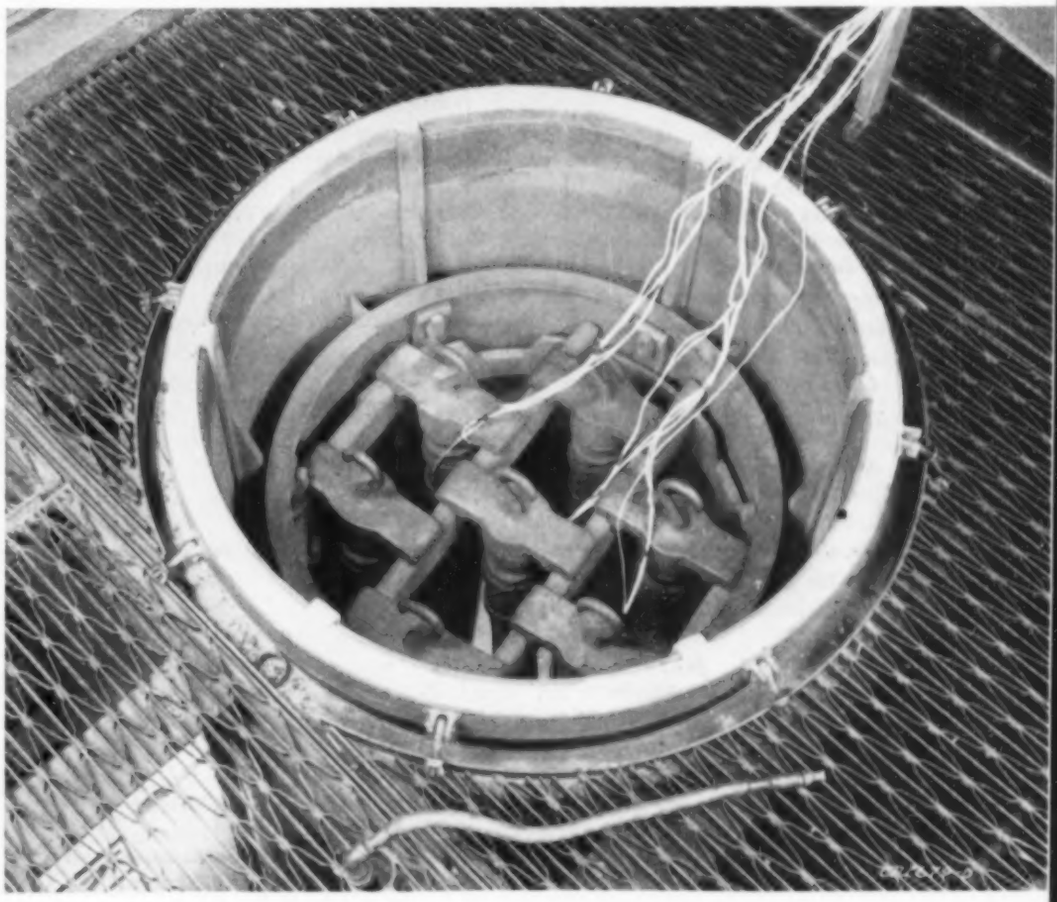
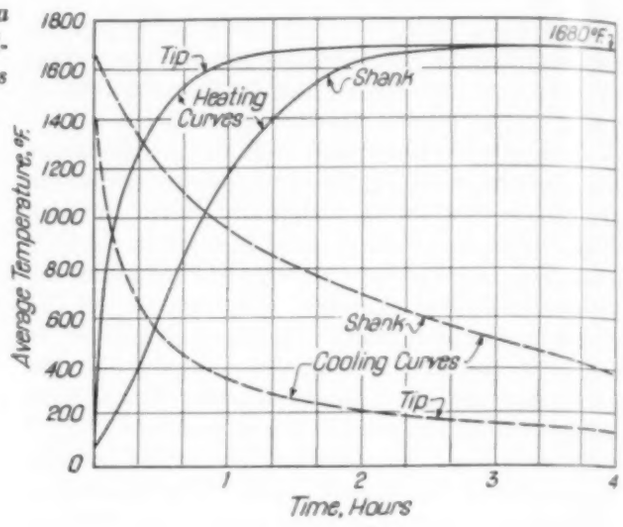


Fig. 7 — Heating and Cooling Curves in a Test Run Surveying and Calibrating a Normalizing Furnace Carrying Four Propeller Blades



Single-blade loads were used to survey the hardening retort, four-blade loads in the normalizing retort, and both four-blade and seven-blade loads for the survey of the low temperature furnace. Two or three control blades were wired in the four-blade loads, and three blades were wired in the seven-blade loads.

Temperature Survey Procedures — The surveys of the normalizing and the drawing operations included the following steps common to both:

1. Loading a cold retort in a cooling pit, purging with atmosphere, and transferring to the furnace pit.

2. Connecting the survey thermocouples (four for normalizing, six for draw or stress relief) to the Tagliabue recorder.

3. Varying the furnace control settings until all surveyed blades were uniformly heated to the desired temperature.

4. Cooling the retort in the cooling pit, thus starting the subsequent and final determination of heating characteristics with a cold load, to simulate intended production operation.

5. Using the control settings determined in accordance with item No. 3 for the final experimental run.

6. Transferring the retort back to the empty cooling pit upon the completion of the final heating survey, to determine the actual blade cooling cycles.

Table I — Heating and Cooling Data, High Temperature General Electric Furnace

	Normalizing	Hardening
Temperature	1680° F.	1680° F.
Load	4 blades	1 blade
Furnace control settings for heating		
Top zone	1705° F.	1700° F.
Top center zone	1705	1700
Bottom center zone	1695	1700
Bottom zone	1695	1700
Time to purge retort	1 hr.	
Time to lower retort in furnace	15 min.	
Time for blades to reach temperature		
After power is turned on		
Tip	1 hr. 50 min.	
Shank	3 hr. 10 min.	
After furnace top center zone reaches temperature		
Tip	20 min.	
Shank	1 hr. 40 min.	
Time to purge blade for hardening		10 min.
Time for blade to reach temperature		
After charging in hardening furnace		
Tip		5 min.
Shank		45 min.
Holding time at temperature	20 min.	45 min.
Time to cool to 600° F. after power is turned off		
Tip	25 min.	
Shank	2 hr. 30 min.	
Total heating furnace time	3 hr. 45 min.	1 hr. 30 min.
Time for complete cycle*	7 hr. 15 min.	1 hr. 40 min.

*Does not include handling time which is approximately 20 min.

The draw furnace surveys differed from the normalizing surveys in that an empty, low temperature retort was soaked for one hour at the required temperature and then withdrawn before the cold retort was charged for the final survey. This was dictated by differences in the intended production schedules.

For the hardening survey, the only requirement was to determine the heating cycles of a single blade. First, the wired blade was used to determine the control settings required to heat it uniformly to the desired temperature. The blade then was allowed to cool to room temperature and again was charged into the hardening retort, whereupon the heating cycles of the tip and shank were recorded with the Tagliabue instrument.

Results of Temperature Surveys — In all, ten complete temperature surveys were performed before the two furnaces were released for production operation. Eight of these surveys were necessary to calibrate the low temperature furnace for

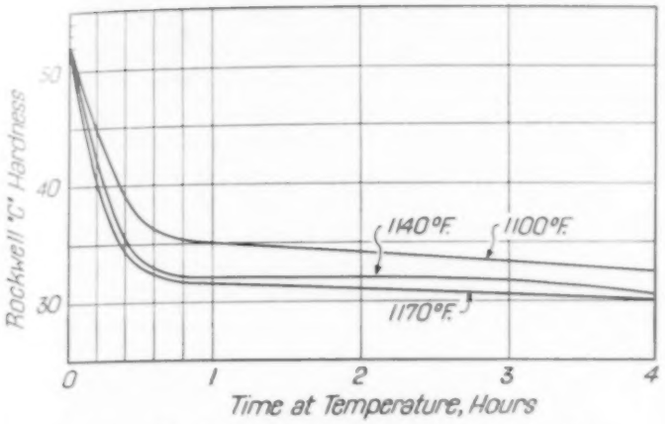


Fig. 8 — Variation in Hardness With Tempering Time in Quenched S.A.E. 4330 (0.32% Carbon)

the various operating temperatures and loads.

Results of the surveys of each furnace are included in a report giving detailed experimental results for each operating condition and recommending the proper operating procedures. These reports either contain photographs of the recorder and controller charts or, better, re-plots of the heating and cooling cycles on ordinary graph paper showing the temperature in degrees rather than the thermocouple emf's. The reports also contain tables listing all pertinent time and temperature data required to operate the furnace properly and to determine its ultimate production capacity. Copies are submitted to the Central Production Engineering Department to form the basis for operation or "shadow" sheets which are posted on the production floor and also used by heat treating inspectors to insure that the operations follow specification requirements.

Figure 7 shows typical heating and cooling cycles based on the average tip and shank temperatures. (Average temperatures would be plotted only when the individual tips and shanks differ no more than a few degrees; otherwise, individual temperatures would be shown.) The load used for this temperature survey was four blades of 836-14C2 design, shank-hung. Control settings for the heating furnace were 1705, 1705, 1695 and 1695° F. for the four zones top to bottom. Table I lists essential operating data for the high temperature furnace, Table II for the drawing operations, and Table III for stress relief cycles.

The original data and operation sheets were based on cooling the blades in a prepared atmosphere to 350° F., to prevent any discoloration of the steel after stress relieving, normalizing, or tempering. Later, to increase the furnace output, the cooling cycles were revised to permit the blades to be removed from the retorts at 600° F. This resulted in a slight, unobjectionable discoloration. The time saved was about two hours for normalizing and one hour each for draw and stress relief. The tables show the revised, shorter cycles.

A careful study of the tables reveals two important facts about the equipment — first, that the furnace control temperature in no instance is the same as the work temperature, and second, that (except for the better load distribution which exists when the blades are tip-hung) the difference between the control setting and the work temperature increases as the top of the furnace is approached. These conditions are due to the fact that the thermocouples actuating the control instruments cannot be inserted in the retorts without interfering with their transfer to the cooling pit, nor can the actuating couples project much

Table II — Data for Furnace on Drawing Operations

Temperature	1140° F.	1140° F.	1140° F.
Load	7 blades, shank-hung	4 blades, shank-hung	7 blades, tip-hung
Furnace control settings for heating			
Top zone	1200° F.	1200° F.	1170° F.
Center zone	1170	1170	1170
Bottom zone	1140	1140	1170
Time to purge retort	1 hr.	1 hr.	1 hr.
Time to lower retort in furnace	15 min.	15 min.	15 min.
Time for blades to reach temperature			
After power is turned on			
Tip	1 hr. 50 min.	1 hr. 40 min.	2 hr. 30 min.
Shank	2 hr. 40 min.	2 hr. 40 min.	2 hr. 30 min.
After furnace top zone reaches temperature			
Tip	45 min.	35 min.	1 hr. 30 min.
Shank	1 hr. 35 min.	1 hr. 35 min.	1 hr. 30 min.
Holding time at temperature	1 hr.	1 hr.	1 hr.
Time to cool to 600° F. after retort is removed from furnace			
Tip	40 min.	40 min.*	45 min.
Shank	1 hr. 25 min.	1 hr. 25 min.*	1 hr.
Total heating furnace time	3 hr. 40 min.	3 hr. 40 min.	3 hr. 30 min.
Time for complete cycle†	6 hr. 20 min.	6 hr. 20 min.	5 hr. 45 min.

*The cooling cycles for these surveys were not run. The values entered in the table are the times to cool to 600° F. of the corresponding 7-blade loads.

†This does not include handling time which is approximately 20 min.

beyond the heating elements without being damaged each time a retort is lowered into the furnace.

This is a disadvantage associated with heat treatment in fully sealed retorts, but since this method permits of any desired number of stress relief treatments, and of normalizing, hardening, and drawing practically without scaling and decarburization, the cost is not too high. It eliminates cleaning of plates after stress relieving before welding, and the cleaning after stress relieving for brazing and after final heat treatment.*

However, the disadvantages mentioned would have indeed been serious and might have condemned these furnaces if blades had been heat treated by mere trial and error methods, but they were reduced to insignificance through the painstaking temperature surveys described above. In the high temperature furnace, the maximum measured variation of the work temperature from the specified 1680° F. was ±2° F., and in the low temperature furnace, the maximum measured variation from the desired temperature was ±3° F., regardless of the time at temperature. Recognizing the fact that the actual work temperature determines the accuracy of the heat treatment, the final heat treating specification for hollow steel propeller blades explicitly calls for work temperatures only.

In addition to enabling us to heat blades accurately to the predetermined temperature, the survey data established total heating times precisely. There was no guess-work or cut-and-try. The laboratory has suitable small furnaces operated by program controls, so the exact heating cycles of thin and thick sections in a work-piece can be duplicated on small specimens and the effect of different heating rates on the final properties can be evaluated. This is quite an obvious advantage for articles as large and variable in thickness as propeller blades, which have to be tempered to the narrow hardness range of Rockwell C-27 to 33, regardless of the chemical variations allowed by the steel specification. It can further be demonstrated on laboratory specimens without difficulty that the hardness during the first 45 to 60 min. at the tempering temperature changes too rapidly for good control, but later changes are quite slow. Figure 8 shows the facts for a certain heat of S.A.E. 4330 steel (carbon 0.32%). With such data at hand it is easy to determine the minimum furnace time for blades made from that heat of steel.

Table III — Heating and Cooling Data for Stress Relief

Temperature	1200° F.	1250° F.	1250° F.	1250° F.	1250° F.
Load	7 blades, before upset, shank-hung	7 blades, before upset, shank-hung	4 blades, before upset, shank-hung	7 blades, after upset, shank-hung	4 blades, after upset, shank-hung
Furnace control settings for heating					
Top zone	1250° F.	1275° F.	1275° F.	1300° F.	1300° F.
Center zone	1225	1275	1275	1275	1275
Bottom zone	1200	1275	1275	1250	1250
Time to purge retort	1 hr.	1 hr.	1 hr.	1 hr.	1 hr.
Time to lower retort in furnace	15 min.	15 min.	15 min.	15 min.	15 min.
Time for blades to reach temperature					
After power is turned on					
Tip	2 hr. 20 min.	2 hr.	1 hr. 40 min.	2 hr.	2 hr.
Shank	2 hr. 30 min.	2 hr. 45 min.	2 hr. 30 min.	2 hr. 50 min.	2 hr. 50 min.
After furnace top zone reaches temperature					
Tip	1 hr. 10 min.	40 min.	25 min.	30 min.	30 min.
Shank	1 hr. 20 min.	1 hr. 25 min.	1 hr. 15 min.	1 hr. 20 min.	1 hr. 20 min.
Holding time at temperature	1 hr.	1 hr.	1 hr.	1 hr.	1 hr.
Time to cool to 600° F. after retort is removed from furnace					
Tip	45 min.	45 min.	35 min.	45 min.	45 min.*
Shank	1 hr. 10 min.	1 hr. 10 min.	1 hr.	1 hr. 30 min.	1 hr. 30 min.*
Total heating furnace time	3 hr. 30 min.	3 hr. 45 min.	3 hr. 30 min.	3 hr. 50 min.	3 hr. 50 min.
Time for complete cycle†	5 hr. 55 min.	6 hr. 10 min.	5 hr. 45 min.	6 hr. 35 min.	6 hr. 35 min.

*The cooling cycles for these surveys were not run. The values entered in the table are the times to cool to 600° F. of the corresponding 7-blade loads.

†This does not include handling time which is approximately 20 min.

*The essential steps in the manufacture of Curtiss hollow steel propeller blades were described in "Welding of Aircraft Propeller Blades", by C. A. Liedholm, *The Welding Journal*, March 1943, p. 165.

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Personals

B. L. AVERBACK has been awarded the Sheffield Foundation fellowship and is studying for his doctorate in metallurgy at Massachusetts Institute of Technology.

EMERSON S. NORRIS has been transferred by Sylvania Electric Products, Inc., from metallurgist, Radio Tube Works, Salem, Mass., to metallurgist, Sylvania Center, Bayside, N. Y.

HERBERT D. STURGES, formerly chairman of the Cincinnati Chapter, has been transferred to the Paterson plant of the Wright Aeronautical Corp. as senior metallurgist.

Chrysler Corp. has transferred JOHN STANFORD from the Dodge Chicago Plant to the Detroit Dodge Forge Division.

Returning to research department, American Can Co., Maywood, Ill.: WILLIAM H. SNAIR, after release from the Army Ordnance Division.

FRANK J. PRYATEL has joined the metallurgical department of the Oliver Corp., Cleveland, following his release from the U. S. Navy.

C. W. SCHEMM has joined the engineering department of the Trumbull Electric Mfg. Co., Norwood Division, Norwood, Ohio.

The Geyer Manufacturing Co. of Rock Falls, Ill., has secured the services of HUBERT STARKEY as heat treat foreman.

HOWARD TAYLOR is studying for his doctorate at Massachusetts Institute of Technology under a fellowship sponsored by the Gray Iron Founders' Society.

After 3½ years active duty with the U. S. Army, H. T. SUMSION has returned to civilian status and the position of metallurgical engineer in the research department of the Tin Processing Corp., Texas City, Texas.

AUGUST PAOLINI, formerly with Boeing Aircraft, is now in the structural test department of the McDonnell Aircraft Co., St. Louis.

ROBERT L. PEASLEE is now research engineer at the Wright Aeronautical Corp., Paterson, N. J.

BERNARD KILBERG, formerly with the Rock Island Arsenal, is now metallurgist-chemist at Deere & Co., Davenport, Iowa.

Pittsburgh Alloy Corp. announces that SAMUEL A. OTT has joined its staff after resigning from Follansbee Steel Corp.

W. S. MOUNCE, formerly senior metallurgist with the Hamilton Standard Propellers Division, United Aircraft Corp., has joined the development and research division of the International Nickel Co., Inc.

BYRON F. CAMPBELL has recently left the Glenn L. Martin Co. and has accepted the position of chief of laboratories for Harry Ferguson, Inc., Detroit.

Returned to the International Nickel Co. of Canada: NEVILLE S. SPENCE, who has been in the Royal Canadian Air Force for 4½ years. Mr. Spence will be attached to the research laboratory of the Mining and Smelting Division.

J. R. STROHM has recently been appointed Chicago district manager of the Copperweld Steel Co. He was formerly with the Dodge Chicago Division of the Chrysler Corp.

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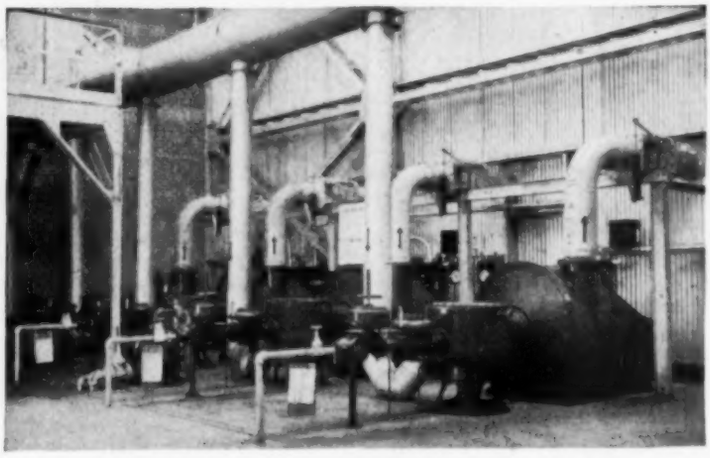

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Personals

The University of Vermont, Burlington, has appointed CARL C. OSGOOD to supervise the manufacturing processes laboratory and teach metallurgical and metallographic laboratory methods to veterans.

S. F. FRENSDORF has been made sales engineer in northeastern Ohio for the Air Filter Equipment Co., Cleveland.

W. W. DYRKACZ has been appointed metallurgical engineer for all plants of the Cameron Mfg. Corp. with headquarters at Emporium, Pa. He was formerly with General Electric Co. in Schenectady, N. Y.

F. A. ELSHOFF has taken over a toy manufacturing plant in St. Petersburg, Fla., and has rechristened it the Elshoff Novelty Co.

J. H. GOODYEAR is now metallurgical engineer in the Aviation Gas Turbine Division of Westinghouse Electric Corp. in South Philadelphia.

RICHARD B. KROPF, formerly with the Copperweld Steel Co., has been made director of the Cincinnati Technical Section of the Development and Research Division of International Nickel Co.

After 11 years with DuPont, MARS G. FONTANA has accepted a professorship in metallurgy at Ohio State University. He is also consulting engineer for the Duriron Co. of Dayton, Ohio.

Formerly with the Westinghouse Electric Corp., H. C. BOSTWICK is now sales agent in the western Pennsylvania and eastern Ohio territory for the Drever Co. of Philadelphia.

CARL LUDWIG has been appointed chief engineer of Adamson United of Akron, Ohio, the plastics and rubber machinery division of United Engineering and Foundry Co.

The election of WM. J. PRIESTLEY, as vice-president in charge of the alloys and metals division of the Union Carbide & Carbon Corp., has been announced.

ROBERT I. MOREEN has been appointed assistant metallurgist at Armour Research Foundation, Chicago.

Formerly Indiana sales manager for General Refractories Co., RAYMOND W. MORGAN has started the Refractory Sales Co. in Detroit.

ROGER F. WAINDLE has been appointed general manager of the Sapphire Products Division of Elgin National Watch Co., Aurora, Ill. He was previously manager of industrial sales for this company.

JOHN T. ROBBINS, formerly senior process engineer of Curtiss-Wright Corp., has joined the technical service staff of Peter A. Frasse and Co., Inc., New York.

A. E. R. PETERKA, formerly lieutenant colonel, Army Air Forces, has resigned from the Reconstruction Finance Corp. to return to the Lamson & Sessions Co., Cleveland.

W. J. LAWLER, formerly with the Aluminum Co. of America, is now sales engineer with the White Metal Rolling & Stamping Corp. of Brooklyn.

FRANK T. SISCO, formerly secretary, Iron and Steel Division, American Institute of Mining and Metallurgical Engineers, has been appointed director of Alloys of Iron Research, Engineering Foundation, New York.

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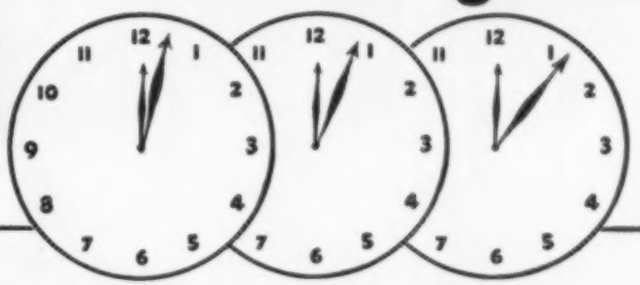
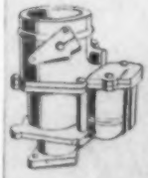


NEW, FAST-ACTION DETERGENT CLEANS FERROUS AND NON-FERROUS METALS...Easy to Handle

TYPICAL USES FOR Solvent "26"



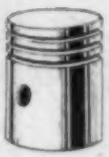
CARBURETORS—Solvent "26" removes gum, gasolene sediment and other accumulations of dirt.

SPARK PLUGS—Solvent "26" safely cleans porcelain; helps loosen carbon deposits.

METAL PLATES AND SCREENS—Solvent "26" restores clear, clean finish to any metal surface.

DIES AND STAMPING—Solvent "26" removes drawing compounds from die-formed or stamped metal.

LABORATORY EQUIPMENT—Solvent "26" frees glass and metal tubing and their supports of gums, varnishes and other incrustations or deposits.



PISTONS—Removes lacquers, gums, resins, etc. from gas, gasolene and diesel engine pistons and rings. Also effective for cleaning all parts of dismantled motors, engines and machinery.

REMOVES:

Oil • Grease • Gums • Varnishes • Lacquers • Paints
Carbonaceous Deposits • Asphaltic Products

FROM:

Steel • Cast Iron • Aluminum • Porcelain • China
Chrome and Nickel Plate • Stone • Precious Metals
Brass • Washable Fabrics

Used throughout the war in critical industry as a superior cleaning agent, newly-developed SOLVENT "26" is now available for all industrial needs.

Offering many advantages in time, labor and cost over other present cleaning methods . . . Solvent "26" is so effective a detergent it can be used at *ordinary* room temperatures.

The fast action of Solvent "26" reduces cleaning time from hours to minutes on dismantled engine parts and all kinds of machinery. Simply dip, rub, brush or spray it on. Then flush clean with hot water.

Mail the coupon today for literature and information leading to a demonstration of this unique product in your own plant.

CITIES SERVICE OIL COMPANY
ARKANSAS FUEL OIL COMPANY

CITIES SERVICE OILS
ONCE-ALWAYS

Cities Service Oil Company
Room 631
70 Pine Street
New York 5, N. Y.

Gentlemen: I am interested in a demonstration of Solvent "26"—at no cost or obligation.

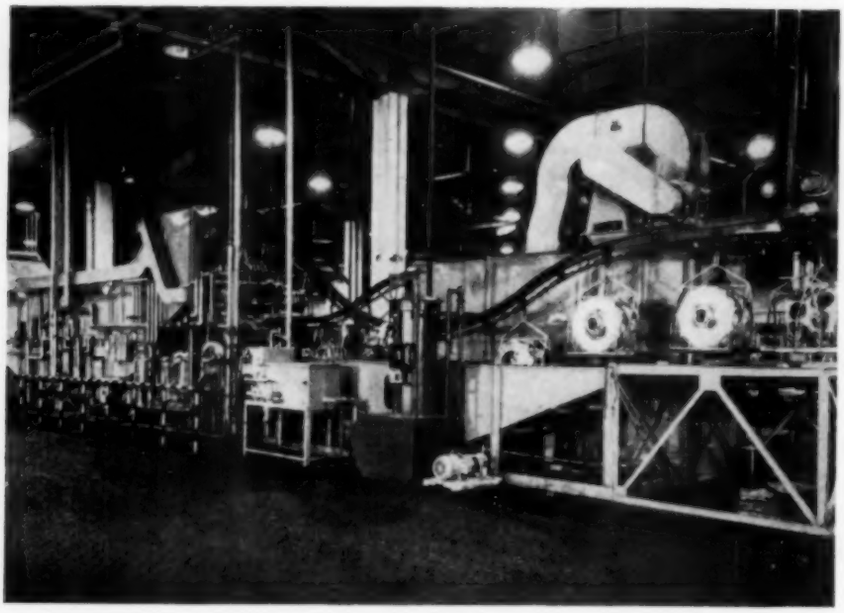
Name.....

Title.....

Company.....

Address.....

City.....State.....



What is your Cleaning Problem?

DETREX PIONEERS CLEANING DEVELOPMENTS

Detrex Corporation has taken part in every major development in metal cleaning for the past quarter century. Pioneering the advancement of solvent degreasing, laboratory research and experience in the field have produced the most highly stabilized of vapor degreasing solvents. Triad Alkali and Emulsion Compounds have kept pace with the rapid development of metal processing. A complete line of case histories has been compiled and from these records the economical answer to every phase of metal cleaning is available.

Thousands of metal cleaning and finishing plants throughout the United States and Canada have found Detrex equipment and chemicals unexcelled in performance. Detrex field representatives, located in every industrial area, are qualified to give unbiased recommendations for your cleaning problems.

Oil
Grease
Dirt
Buffing Compounds
Drawing Compounds
Plating
Magnaflux
Painting
Blackening
Rust Proofing
Quenching Oils
Pickling
Paint Spray Booths
Electric Cleaning
Anodizing
Lapping Compounds
Aluminum
Magnesium
Mixed Metals

DETREX *Corporation*

DETROIT 27 • MICHIGAN

Solvent Degreasers • Metal Parts Washers • Processing Equipment • Industrial Cleaning Chemicals

Personals

CHARLES T. FRUECHTENICHT, formerly with the General Electric Co., is engineer in the development section of control division, Iron Fireman Mfg. Co., Portland Ore.

A new department of metallurgy is being organized at the University of Pennsylvania, Philadelphia, by R. M. BRICK, who came to that institution from Yale University.

A. W. SIKES, recently returned to inactive status after nearly five years in the U. S. Army, has joined the staff of L. A. Cohn & Bro., Inc., Chicago.

ARCHIBALD BLACK has terminated his connection with Simmonds Aerocessories, Inc. and is doing organization work for the International Civil Aviation Organization, Montreal.

RAYMOND VINES, formerly with Ford Instrument Co., is now metallurgist for Dentists Supply Co., York, Pa.

The U. S. Time Corp. of Waterbury, Conn., has secured the services of WILLIAM H. MILLER as metallurgist.

C. J. GASPAR has been associated with the Nichols Wire & Steel Co., Davenport, Ia., as special representative since his release to inactive duty by the U. S. Navy.

Following his release from active duty with the Ordnance Division, GEORGE M. ENOS has been engaged in consulting engineer work and became professor of metallurgical engineering at Purdue University on Feb. 1.

ARTHUR H. GROBE, formerly of the Carnegie Institute of Technology, has been appointed chief research metallurgist of the Vanadium-Alloys Steel Co. of Latrobe, Pa.

Promotions announced: W. PAUL EDDY, JR., to position of chief of engineering operations and GORDON WILLIAMS, to materials engineer at Pratt & Whitney Aircraft Division, East Hartford, Conn.

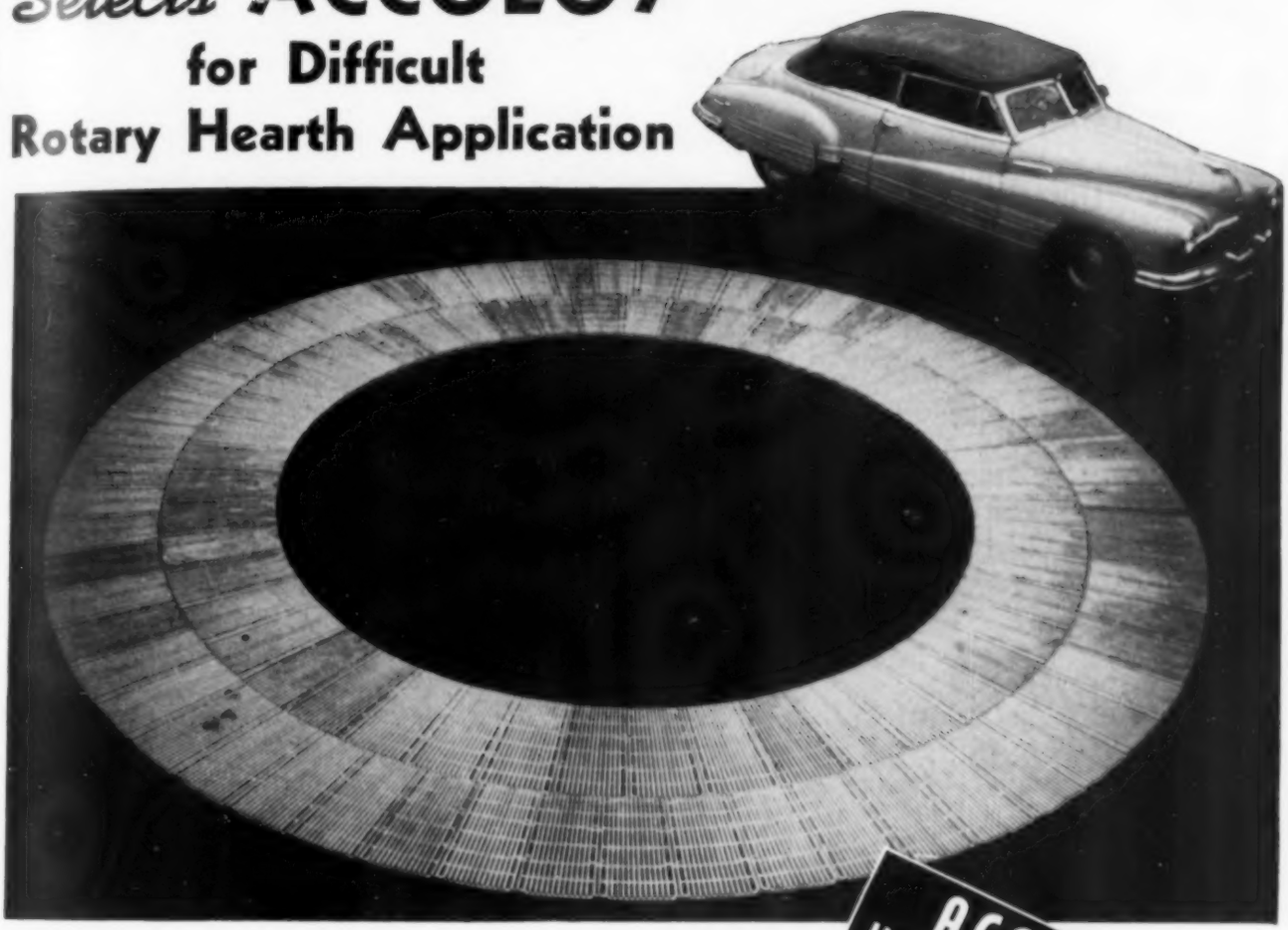
Named chairman of the Gray Iron Division of the American Foundrymen's Association: T. E. EAGAN, chief metallurgist of the Cooper-Bessemer Corp., Mount Vernon, Ohio.

LEO J. T. BROM has become an active partner in the Frank J. Brown Machine & Foundry Co., Winona, Minn.

STEWART INDUSTRIAL FURNACE DIVISION

Selects ACCOLOY

for Difficult Rotary Hearth Application



Patent Pending

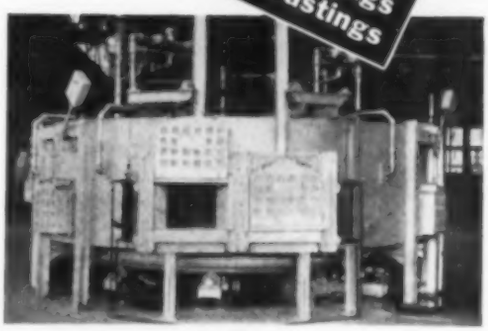
The 24 foot diameter CRISS-CROSS Articulated Rotary Hearth pictured above was designed by ACCOLOY ENGINEERS, in collaboration with Engineers of Stewart Industrial Furnace Division of Chicago Flexible Shaft Company, to meet the exacting requirements of a special cycle annealing Rotary Hearth Furnace with several heating zones.

OUTSTANDING CHARACTERISTICS

- CRISS-CROSS intersecting ribs assure uniform surface-to-mass ratios, thereby eliminating self-destructive stresses during cyclic heating and cooling.
- Interlocking of segments permits each to expand and contract independently, eliminating unnecessary strain, warpage and premature self destruction.
- Line contact of radial ribs provides uniform heating and ease of loading and unloading of material.
- Individual segments easily replaced.
- Adaptable to any type furnace hearth.

Complete details furnished on request.

ACCOLOY
Heat Resistant Castings
Stainless Steel Castings



STEWART Rotary Hearth Furnace

Send us your next inquiry for HEAT RESISTANT and STAINLESS STEEL CASTINGS.

NEXT TIME CALL AN ACCOLOY ENGINEER

ACC

ALLOY CASTING COMPANY

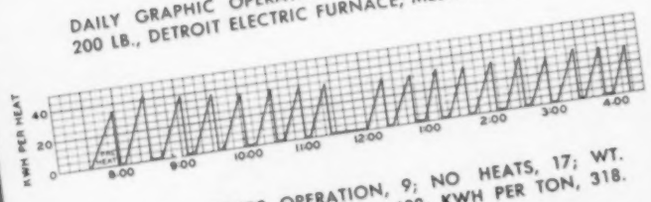
CHAMPAIGN, ILLINOIS

Engineering Offices in Principal Cities

NEW TYPE DETROIT ELECTRIC FURNACE SIMPLIFIES SHELL INTERCHANGE

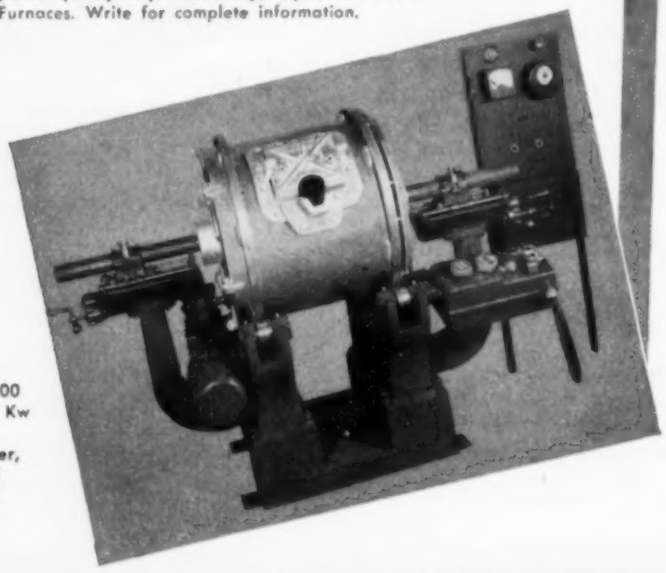
Operating Record in melting of Red Brass reveals production efficiency

DAILY GRAPHIC OPERATING RECORD, TYPE LF, 75 KW, 200 LB., DETROIT ELECTRIC FURNACE, MELTING RED BRASS.



SUMMARY: HOURS OPERATION, 9; NO HEATS, 17; WT. PER HT., 225 LBS.; Kwh TOTAL, 608; KWH PER TON, 318.

Simplified in construction, more compact in design, the new type LF, 200 lb. Detroit Rocking Electric Furnace illustrated below will speed production melting of ferrous and non-ferrous metals in your foundry at reduced cost. In a typical day's operation, this modern furnace melted 17 heats of red brass—225 lbs. per heat—in 9 hours. That's 3825 lbs. of superior quality metal produced with clock-like precision throughout the day with a total overall energy consumption of only 318 Kwh per ton. Power is brought in to the electrodes from either above or below by copper conductors to the stationary pedestal type supports of the non-rotating electrodes. Interchanging of furnace shell involves only the withdrawal of the electrodes allowing the shell to be lifted since there are no detachments to be made. Base mounted electrode brackets, complete with meter panel and contactor box, provide a clear, untrammeled working area for the operator who has all controls at his fingertips. For faster, cleaner production of castings of superior quality in your foundry, depend on Detroit Rocking Electric Furnaces. Write for complete information.



New type LF, 200 lb. capacity, 75 Kw Detroit Electric Furnace for faster, more economical foundry melting.

DETROIT ELECTRIC FURNACE DIVISION
KUHLMAN ELECTRIC COMPANY • BAY CITY, MICHIGAN

Personals

The Timken Roller Bearing Co. announces the appointment of HARRY MCCOOL as sales engineer for the Steel and Tube Division in the Cincinnati district.

ROLLAND R. LAPELLE, formerly manager of the special furnace division, has been elected vice-president of Dempsey Industrial Furnace Corp., Springfield, Mass.

The John Harsch Bronze & Foundry Co. announces the appointment of L. A. KRISTOFF to head its new permanent mold castings division.

Meritorious Civilian Service Award was presented to NOAH A. KAHN for services and achievement as head metallurgist of the New York Naval Shipyard.

Promotions by the Aluminum Co. of America: L. W. KEMPF, formerly manager of the Cleveland Research Division, now an assistant director of research for the entire company; KENT R. VAN HORN, from assistant manager to manager of the Cleveland Research Division.

PAUL A. BECK, formerly superintendent of the metallurgical laboratory at the Cleveland Graphite Bronze Co., has joined the metallurgical department of the University of Notre Dame, Notre Dame, Ind.

The Ohio Stainless Steel Co., Cleveland, announces the appointment of ALLEN HURT as sales manager. Mr. Hurt was formerly associated with the Federal Telephone & Radio Corp.

HERBERT F. SCOBIE has joined the staff of the American Foundrymen's Association in Chicago, leaving the University of Minnesota where he taught foundry practice.

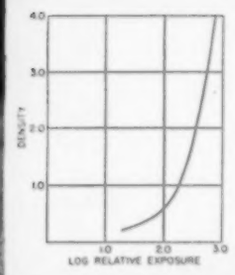
OSCAR G. JOHNSON, formerly with the Wright Aeronautical Corp., Lockland, Ohio, has become affiliated with the Menasco Mfg. Co., Burbank, Calif.

Latrobe Electric Steel Co., Latrobe, Pa., has secured the services of STEWART G. FLETCHER as chief research metallurgist. He was previously a research associate at Massachusetts Institute of Technology.

A. J. FAZIO has been promoted to the position of general superintendent of the Braeburn Alloy Steel Division of Continental Industries, Inc., Braeburn, Pa.

Q. Which x-ray film for examination of 3" castings at 1000 kv.?

A. Kodak's Type A



Characteristic Curve, Kodak Industrial X-ray Film, Type A: with direct x-ray exposure or with metallic screens. Development: 8 minutes, at 68° F., in Kodak Rapid X-ray Developer, or Kodak Liquid X-ray Developer and Replenisher.

IN THE CASE of castings like this, good radiographic practice calls for Kodak Industrial X-ray Film, Type A.

This film, used with lead screens, gives excellent detail, high contrast. The fine grain of Type A helps radiographers detect slag, tears, porosity, and other irregularities in castings of this size, and its speed is more than adequate to meet the need of rapid investigation.

Your Kodak dealer now has ample supplies of Kodak industrial x-ray films.

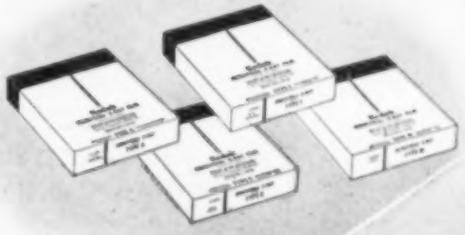
Kodak also offers these 3 additional important types of industrial x-ray film

Kodak Industrial X-ray Film, Type K . . . primarily meant for gamma and x-ray radiography of heavy steel parts, or of lighter parts at low x-ray voltages where high film speed is needed.

Kodak Industrial X-ray Film, Type F . . . with calcium tungstate screens—primarily for radiography of heavy steel parts. The fastest possible radiographic procedure.

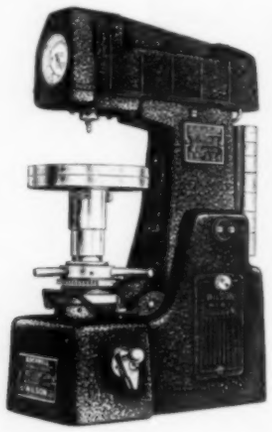
Kodak Industrial X-ray Film, Type M . . . first choice for critical inspection of light alloys or, with million-volt radiography, of thin steel and heavy alloy parts.

EASTMAN KODAK COMPANY
X-ray Division, Rochester 4, N. Y.



Kodak

"ROCKWELL"
HARDNESS TESTER



Improvements in Latest Models

1. Elevating Screw now made of Stainless Steel
2. Ball Chuck now made of Stainless Steel
3. Plunger Rod Base now made of Stainless Steel
4. Stem of Plunger Rod now Hardened and Ground
5. Testing Head and Dial now Totally Enclosed
6. Penetrator Clamp Screw now an Automatic Clamp
7. All Operation Controls now Bunched Together
8. Dial of Gauge now has Zerominder Scale for Speed
9. Finish now Greatly Improved over War Times

Most used testers of our make lack all of these 9 things and all but those made within the past twelve months lack many of them.

ACCO

WILSON
MECHANICAL INSTRUMENT CO., INC.
367 Concord Avenue, New York

An Associate Company of American Chain & Cable

Personals

R. H. THIELEMANN has become development engineer of Pratt and Whitney Aircraft Division in East Hartford, Conn., after resigning from a similar position at the Allegheny Ludlum Steel Co.

Pennsylvania State College has secured the services of JAMES R. COXEY, formerly metallurgist at the Wright Aeronautical Corp., Cincinnati, Ohio.

CLIFFORD E. HORNER has been appointed head of the research department of J. F. Jelinko & Co., New York City.

A. A. GUSTAFSON is operating the Harris Calorific Sales Co. and the A. A. Gustafson Co., St. Paul, Minn.

R. EDSON EMERY, formerly president of the Jessop Steel Co., Washington, Pa., has been elected chairman of the board.

ROBERT M. BUCK has been appointed to the development staff of the industrial division of the Bryant Heater Co., Cleveland.

Universal-Cyclops Steel Corp., Bridgeville, Pa., announces that WILLIAM H. NORRIS, formerly with the Allegheny Ludlum Steel Corp., is manager of the Titusville plant; W. J. LONG, previously assistant general sales manager, is now manager of tool steel sales; L. S. FULTON, formerly with Crucible Steel Co., is stainless metallurgical engineer.

W. A. PERRY has been promoted to assistant to the general superintendent of the Inland Steel Co., Chicago.

A. A. BRADD has been appointed assistant superintendent of research at the Midvale Co., Philadelphia. He was previously laboratory director at Remington Rand Propeller Division.

THOMAS B. BLACKWOOD has joined the metallurgical department of the Vanadium-Alloys Steel Co., Latrobe, Pa., coming from Universal Cyclops Steel Corp.

W. F. GOETZ has been appointed manager of the Pittsburgh office and warehouse of A. Milne & Co.

The newly organized Chester Electric Steel Co., Chester, Pa., will be headed by FRED GROTTS, president of Fort Pitt Steel Casting Co. since 1939.

COLGATE

"ENGINEERED SERVICE," FACILITIES AND SKILL IN

Aluminum, Magnesium and Stainless Steel

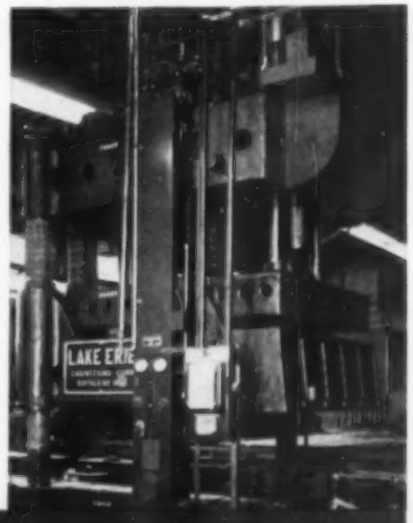
This precision fabricated assembly demonstrates COLGATE'S specialized "know-how," engineering ingenuity, and complete facilities for working with the light metals. Simple as it looks, the end use of this assembly necessitated the creation of positive tooling in order to attain the exact interchangeability required, as well as overcome the problems concerned with stamping, forming and welding operations — all of which were solved before mass production was started. This was accomplished by continuous "Engineered Service" conferences resulting in the saving of time, money and materials and the delivery of a quality product on time.

From the rough-idea stage to final assembly, COLGATE can help solve your problem of developing new products, improving old ones, substituting light metals for other materials. COLGATE can supply the "know-how" for special parts fabrication and assembly and in essence give you additional plant facilities without investment. COLGATE'S specialized experience, complete and centralized facilities, latest mass-production assembly techniques all contribute to meet your exacting specifications and delivery dates. Where blueprints are already prepared we will fabricate and assemble parts to your specifications.

Let COLGATE show you how these sales-creating product features — *light weight, increased strength, durability, added beauty and improved performance* can make light metals a desirable substitute for heavier materials. Learn how COLGATE'S "Engineered Service", facilities and skills can help make your product faster, better, more economically. Your inquiry is invited, prompt attention and complete confidence assured.

COLGATE has a variety of hydraulic presses ranging from 10 to 750 ton capacity and mechanical presses from 2½ to 200 tons capacity. Complete and centralized facilities for—

STAMPING	WELDING
FORMING	FINISHING
DRAWING	ASSEMBLING

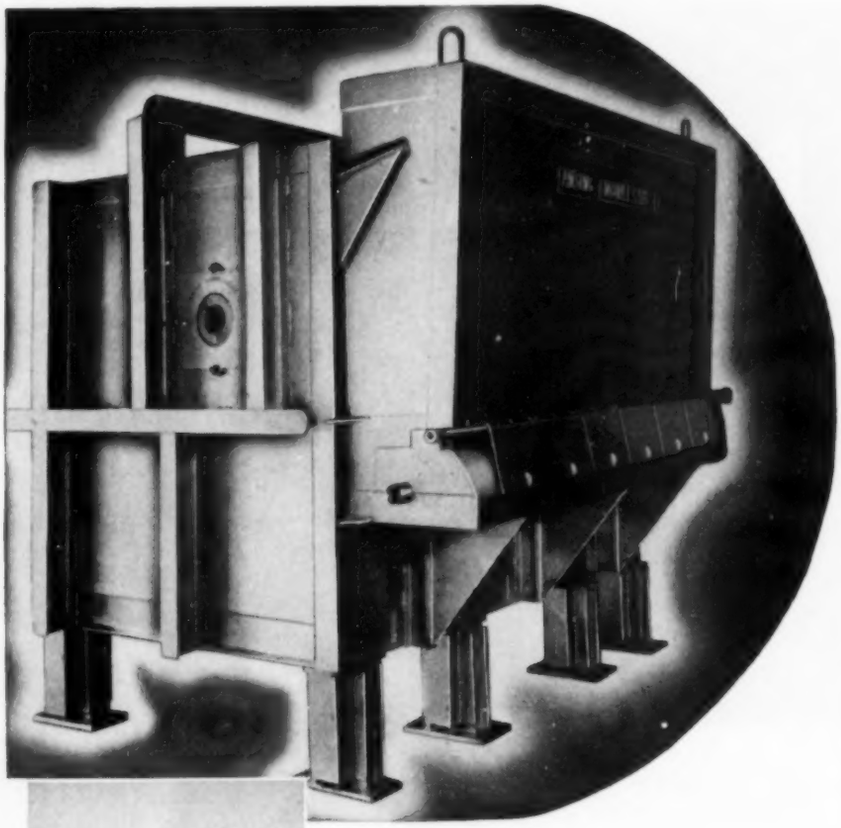


COLGATE

Corporation

NEW YORK

LIGHT METAL PRODUCTS DIVISION



INDUSTRIAL
HEAT TREATING
FURNACES
for:
CARBURIZING
NORMALIZING
HARDENING
ATMOSPHERE CONTROL
TEMPERING
STRESS RELIEVING
ANNEALING
NATURALIDING
BRAZING
CYANIDING
CYCLE ANNEALING

Lansing
SHOCK ABSORBER
Forging Furnace

Supporting legs have hammer-shock dampening springs that greatly increase life of Furnace lining material. Interior of Furnace quickly accessible through full width raisable front section. Sliding front flaps conserve interior heat and protect operator. Furnace completely insulated for maximum operating economy.

LANSING ENGINEERING COMPANY
934-36 Clark Street - LANSING 6, MICHIGAN

Scuffing of Gears*

A SERIES OF TESTS to determine the effectiveness of various surface treatments in preventing or delaying failure of gears by scuffing has been carried out by the Automobile Research Committee of the Institution of Automobile Engineers in Great Britain. The treatments applied to the gears were essentially the same as those applied in this country to piston rings and other parts to prevent scoring.

To be satisfactory, a treatment must meet the following requirements: *(a)* It must give appreciable protection against scuffing; *(b)* the gear must not be made more susceptible to failure by pitting or tooth breakage; *(c)* the dimensions and shape must not be materially changed. Treatments at over 300° F. would not do for ordinary case-hardened gears, else they would be softened by tempering.

Several treatments seemed worthy of study, such as phosphate, caustic soda-sulphur, electrolytic tin plating, anodic deposition of colloidal graphite, and nitric acid etch.

Three types of tests were run: *(a)* Direct scuffing tests to determine the degree of protection initially imparted to the gear; *(b)* running-in tests to determine the lasting quality of the treatment; and *(c)* endurance tests to indicate if the treatment had any effect upon the liability to fatigue failure.

All gears were casehardened S.A.E. 4615. The gears for the first two types of tests had almost unmodified involute profiles while those used for the endurance tests were relieved to discourage scuffing.

Preliminary tests showed the relative scuffing loads in Table I.

Table I	Direct Test	Test After 40 Hr. Running-In
Untreated gear	1.00	
Deep phosphate (Mn) *	2.22, 2.05	1.66, 2.03‡
Shallow phosphate (Zn) † (2)	1.46, 1.36	1.46, 1.50‡
Caustic soda-sulphur	1.29	
Tin plate	1.00	
Colloidal graphite	1.21	

*45 min. at 206° F. in proprietary solution of ferrous and manganese dihydrogen phosphates.

†10 min. at 180° F. in proprietary solution of ferrous and zinc dihydrogen phosphates with nitrates.

‡After 100 hr. running-in.

(Cont. on p. 382)

★Abstracted from "Chemical Surface Treatments for Gear Teeth", *Automotive Industries*, July 1, 1945, p. 40.

Enduro Pays in many ways

High strength and long life are two qualities of Republic ENDURO Stainless Steel which pay profitable long-term dividends in chemical and other processing applications.

Containing approximately 115 tons of ENDURO, the ammonia oxidation towers shown below were erected in 1926. Today, after twenty years of continuous service, they are reported to be, structurally, as sound as when they were installed.

Hundreds of other long-time ENDURO installations afford additional proof of the long, trouble-free service which ENDURO provides.

For complete information about these and the many other reasons why it pays to specify Republic ENDURO Stainless Steel in your equipment, write directly to:

REPUBLIC STEEL CORPORATION
Alloy Steel Division • *Massillon, Ohio*
GENERAL OFFICES • CLEVELAND 1, OHIO
Export Department: Chrysler Building, New York 17, New York

- Improved Employee Relations
- Easy to Clean
- Non-Contaminating
- ✳ Strong—Long Lasting
- Resistant to Rust and Corrosion
- Resistant to Heat
- Easy to Fabricate
- Universal Acceptance
- Low Ultimate Cost

Typical of the many processing applications for Republic ENDURO Stainless Steel are these ammonia oxidation towers. Others include autoclaves, condensers, conveyors, evaporators, heat exchangers, valves, vats, tanks and many types of equipment.

Republic
ENDURO STAINLESS STEEL
Reg. U. S. Pat. Off.

Other Republic Products include Carbon and Alloy Steels—Pipe, Sheets, Strip, Plates, Bars, Wire, Pig Iron, Bolts and Nuts, Tubing

where
VIBRATION ABSORPTION
is essential

specify
ABSCO-MEEHANITE
castings

With Absco-Meehanite castings, you can control closely the physical properties demanded by a specific application. For example, if you need a base for a machine tool, such as the Absco-Meehanite casting illustrated, you must have, first of all, vibration absorption in the metal. Yet this property must be combined with the necessary degree of strength and toughness.

Combining the dual characteristics of iron and steel, this Absco-Meehanite casting maintains superior damping at high stress ranges while providing reliable, substantial support . . . promotes smooth, less noisy operation.

If you want unusual castings for unusual service *on a production schedule basis,* consider Absco-Meehanite castings. In them are combined the experience-based foundry knowledge, techniques and facilities of American Brake Shoe Company. Write and tell us your casting needs.

Brake Shoe

BRAKE SHOE AND CASTINGS DIVISION
230 Park Ave., New York 17, N. Y.

ABSCO-MEEHANITE PROPERTIES

1. Strength (Shear, Compressive, Tensile and Transverse)
2. Impact Resistance
3. Corrosion Resistance
4. Wear Resistance
5. Heat Resistance
6. Toughness
7. Rigidity
8. Machinability
9. Pressure Tightness
10. Vibration Absorption

4405

Scuffing of Gears

(Continued from page 380)

Additional tests did not duplicate the favorable figures shown for the deep phosphate treatment, yet these tests were so promising that all further tests were made with the phosphate treatments only. Table II summarizes these results for the relative scuffing loads.

Obviously the three deep phosphate treatments gave the best results. Endurance tests were made but in all tests the gears failed by tooth breakage and not by pitting.

Profile measurements were not adequate to measure wear, particularly after the deep phosphate treatments where there appears to be an appreciable build-up of a comparatively soft coating which is rubbed off quickly. Furthermore, despite the consistently good protection against scuffing shown by the deep phosphate treatments, the wear indicated by profile measurements showed considerable variation from one batch to another.

Table II

	Direct Test	Test After 100 Hr. Running-In
Untreated gear	1.00	0.85
Cool shallow phosphate (Zn)*	1.61	1.09
Deep phosphate (Mn)† (6)	2.10	1.98
Shallow phosphate (Zn)‡	1.50	1.25
Accelerated deep phosphate (Mn.)**	2.08	1.87
Treatment (2) prolonged (Zn)††	1.69	1.18

*20 min. at 115° F. in proprietary solution of zinc dihydrogen phosphate and nitrate.

†30 min. at 210° F. in proprietary solution of ferrous and manganese dihydrogen phosphate.

‡5 min. at 175° F. in proprietary solution consisting essentially of zinc dihydrogen phosphate with an accelerating agent.

**15 min. at 190° F. in a solution similar to the deep phosphate solution noted * in the first table.

††Same as treatment marked † in first table, except for 30 min. duration.

The phosphate treatments appear to be the most effective surface treatment for inhibiting scuffing of gears. The manganese phosphate baths (those giving a relatively deep and usually coarse-grained coating) give the greatest protection against scuffing, as they approximately double the load required to cause scuffing in the gear testing machine used. This

(Continued on page 384)

Yes, it's an Alcoa Aluminum die casting

Aluminum's natural lightness and the thin sections in Alcoa's die castings make this frame easy to handle. Aluminum's superior thermal conductivity transfers heat to the baking pans in a hurry. Furthermore, due to the ability of ALUMINUM die castings to withstand the elevated temperature of the baking oven, permanent shape and the required strength are assured.

Alcoa's range of equipment for producing Aluminum die castings covers the field. The same care and know-how are employed in the making of the smallest as well as the largest of Alcoa's die castings.

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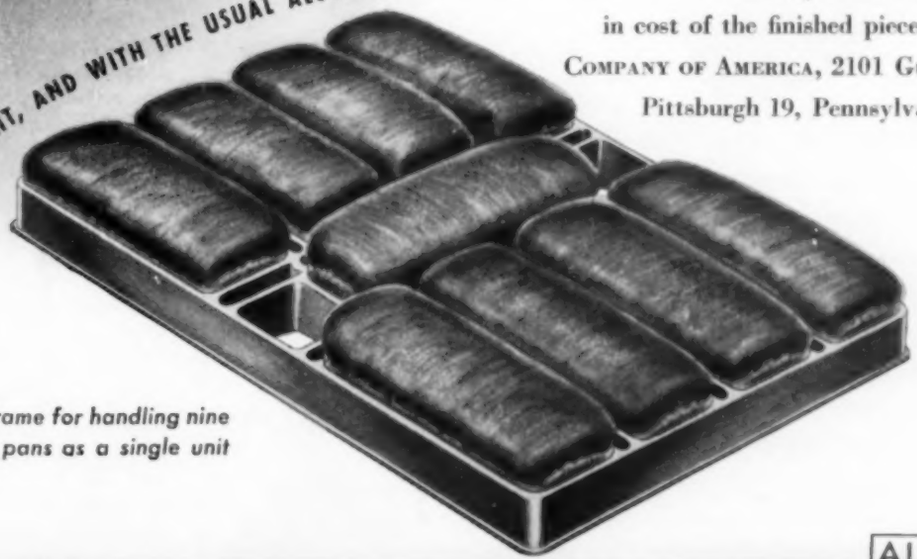

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Scuffing of Gears

(Continued from page 382)

improvement was maintained after running the gears for 100 hr. at about 80% of the load required to cause scuffing of the untreated gears. The amount of wear during this 100 hr. was greater than the amount of build-up but was limited to a few ten thousandths of an inch. Zinc phosphate treatments gave less protection than manganese phosphate. These treatments varied greatly in their ability to retain the anti-scuffing properties after running-in. Although no conclusive evidence was obtained on the liability of the gears to fail by fatigue, the indications were that the surface treatments did not increase the liability to failure by tooth breakage.

Phosphate treatments appear sufficiently promising to warrant experimental application where scuffing is likely to occur.

Graphitization in Steam Lines*

A JOINT SUBCOMMITTEE on Graphitization set up by the Edison Electric Institute and the Association of Edison Illuminating Companies initiated an investigation at Battelle Memorial Institute to study the fundamental causes of graphitization in low carbon steel. The present facts appear to be particularly pertinent.

Deoxidation with aluminum promotes graphitization but the rate of graphitization is proportional to the metallic aluminum rather than to the aluminum oxide content. The aluminum also gives an abnormal structure in the McQuaid-Ehn test. Segregated and embrittling graphite has been found only in fine-grained, aluminum deoxidized steel, although a small amount of random graphite has been found in coarse-grained steel. A shift has gradually been made to coarse-grained steel in the past few years on the basis of accumulated data indicating that improved creep resistance accompanies the coarse grain. A coarse-grained hot upset structure is believed to be more susceptible to segregated graphite formation than a fine-grained normalized steel.

A structure of pearlite and ferrite is believed to be more stable

(Continued on page 386)

*Abstracted from "Progress Report on Graphitization of Steam Lines", by S. L. Hoyt and R. D. Williams, *Welding Journal*, May 1945, pp. 274s-282s.

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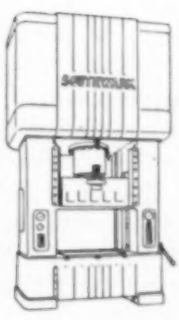

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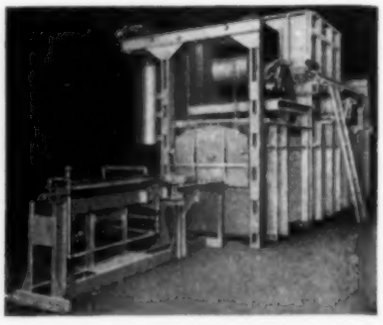

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Graphitization

(Continued from page 384)

than the so-called Widmanstätten structure. There is some indication that graphite nuclei may be playing an important part. Temperature fluctuations are a minor factor, since graphite has been found even in samples held within very narrow temperature ranges. Information to date suggests that stress acts as an accelerator and is not a primary cause of the graphitization. Molybdenum in these steels acts to retard the formation of graphite.

It is becoming clear that welding conditions probably have a pronounced effect on the graphitization, particularly on the formation of segregated graphite. A narrow heat band and a relatively high speed of welding are reported to favor graphitization. It is not known whether welding is a major factor in determining whether graphite will be formed or whether it is a secondary factor controlling the rate at which graphitization proceeds when other factors are favorable.

If graphitization has proceeded only to an intermediate stage in a pipe line, the graphite should be redissolved by 2 hr. at 1700° F. The present indications are that localized graphite will not be formed after this treatment. In cases of severe segregated graphite, it is necessary to cut out the old joint and reweld. A stress relief at about 1200° F. retards graphitization even if it does not prevent it.

The recommendation has been made that a maximum aluminum addition of ½ lb. per ton (or the nearly equivalent requirement of 1 to 5 McQuaid-Ehn grain size with complete normality) be used for steel for new lines although there are drawbacks for some products. Another suggestion has been the addition of chromium to stabilize the carbide. It is not yet clear whether normalizing is worth the extra cost.

The Battelle program has definitely identified the constituent in question as graphite. Carbon-molybdenum steels were proven to be appreciably more resistant to graphitization than carbon steels. Carbon and carbon-molybdenum steels deoxidized with aluminum (1.5 to 2 lb. per ton) were more susceptible to graphite formation than similar steels deoxidized with smaller amounts of aluminum. To date, segregated graphite has been found in the weld-heat-affected

(Continued on page 388)

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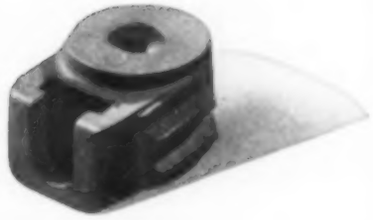

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Graphitization

(Continued from page 386)

zone of the carbon steel but not of the carbon-molybdenum steel. The present data indicate that material air cooled from 2200° F. was more resistant to graphitization than material air cooled from 2200° F. and then from 1650° F. Specimens stress relieved at about 1300° F. were in general slightly more susceptible to graphitization than those stress relieved at 1200° F. Either stress relieving treatment decreased the susceptibility to graphitization of welded specimens. Tests are being made to determine the required amount of chromium and possibly titanium necessary to stabilize the carbide.

Residual Elements in Cast Iron*

IMPORTANCE must be attached to the influence of residual elements in cast iron, particularly in view of the possibility of contamination by the less usual elements, such as boron, present in much of the scrap made available by the war. Even less than 0.1% aluminum will make gray iron from an iron which would otherwise be white or mottled. Small amounts of boron or tellurium have the opposite effect.

Behavior in service cannot be consistently predicted by the chemical composition of cast iron as normally determined. For example, Silal (about 2% carbon, 5.5% silicon) may have three types of structure: *(a)* Ferrite plus fine graphite; *(b)* pearlite plus coarse graphite; and *(c)* pearlite, coarse graphite and carbides or silicides. By far the best oxidation resistance is shown by structure *(a)*. However, routine chemical analyses give no indication of the cause of structural differences which may be displayed by specimens of the same size and shape.

A somewhat similar experience has been encountered with Ni-Resist. Pump castings with coarse graphite in the structure were completely unsatisfactory in service as compared with alloys having a fine graphite, although the chemical compositions as normally determined were practically identical.

(Continued on page 390)

*Abstracted from "Residual Elements and Gas Contents of Cast Iron", by J. E. Hurst, *Metallurgia*, Nov. 1945, pp. 9-12.

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Cast Iron

(Continued from page 388)

American cylinder castings had very similar chemical compositions to normal British castings although there were marked differences in machinability as well as wear resistance. The American castings had more ferrite. Gas analyses showed about the same oxygen and nitrogen in both but the American casting had 7.8 ml. hydrogen per 100 g. as compared to 3.3 for the British. A difference in the residual titanium (0.09% in the British castings; 0.05% in the American) may be important.

Blackheart malleable castings had practically the same normal analyses although one had a dull black, desirable fracture while the other had a bright, crystalline fracture. Residual and gas analyses showed a significant difference in the titanium, aluminum and nitrogen with the lower aluminum and nitrogen contents and the higher titanium content corresponding to the more desirable fracture.

An abnormally high incidence of subcutaneous pinholing in high silicon acid resisting iron castings was found to be due mainly to high hydrogen contents. When the hydrogen was over 2 ml. per 100 g., difficulties were invariably encountered with both pinholes and blowholes.

Much more investigation is needed in this field. It is hoped further work will help to explain variations among cast irons of the same "normal" chemical composition and will facilitate consistent production of sound castings capable of giving good service.

Silver-Thallium Bearings*

A SERIES of fused silver-thallium alloys with 0.5 to 10% thallium was tested. A homogenizing treatment at 840 to 1020° F. was necessary to eliminate the cored structure. Microscopic examination and the steep drop in electrical conductivity indicated the formation of a solid solution up to about 9 to 10% thallium. The tensile strength, elongation and reduction of area were higher in almost all cases in the homogenized than in the cast condition. All these

(Continued on page 392)

*Abstracted from "Silver-Thallium Antifriction Alloys", by F. R. Hensel, American Institute of Mining and Metallurgical Engineers Technical Publication No. 1930, 14 pp.

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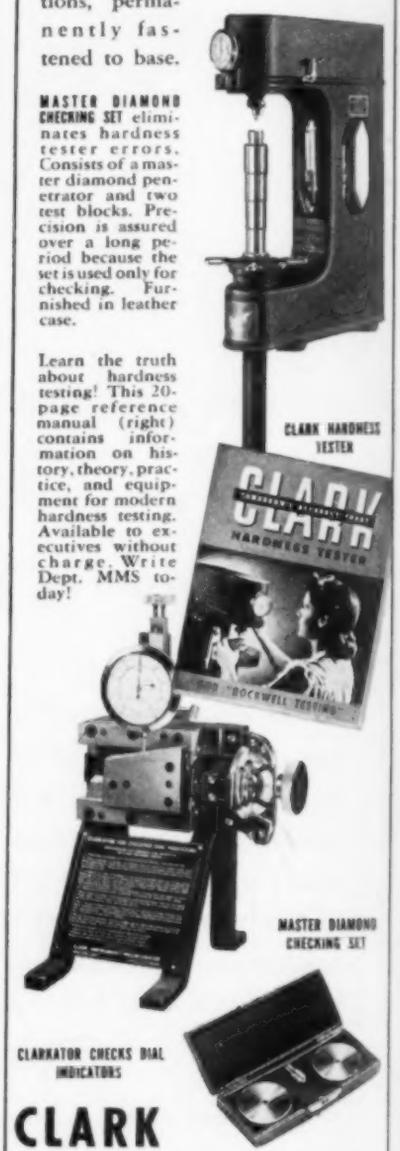

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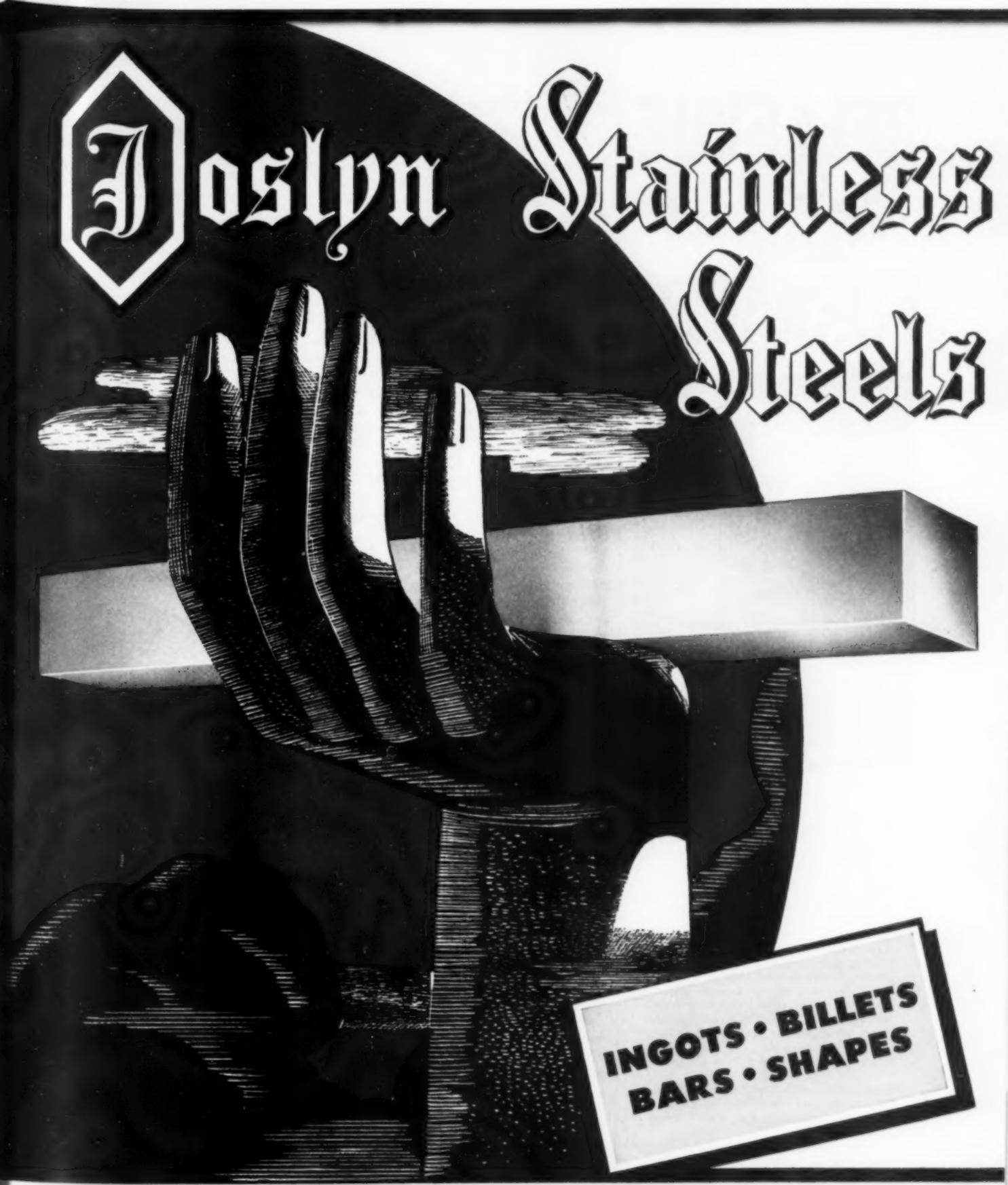

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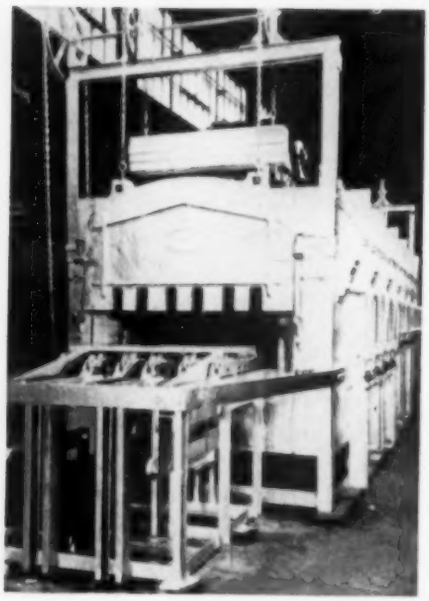

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Silver-Thallium Bearings

(Continued from page 390)

values decreased with increasing thallium content. Hardness was somewhat erratic, especially for the lower thallium alloys.

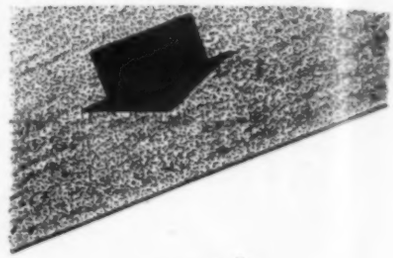
Silver-thallium alloys with thallium contents from a few hundredths to 11.35% were prepared by electroplating from cyanide and perchlorate baths. Electroplated alloys tended to have higher tensile strengths than the fused alloys but slightly lower elongations and electrical conductivities. A homogenization treatment eliminated internal stresses, preferred orientation and non-uniform grain size as indicated by X-ray and microstructure studies.

Preparation of a silver-thallium alloy bearing surface by diffusion was studied. Thallium was electroplated on silver and then heated for 6 hr. in hydrogen at 930° F. (starting the furnace from room temperature). A steep diffusion gradient was obtained, which was flattened considerably when the temperature was increased to 1110° F. Alloy layers 0.003 in. thick with 2 to 3% thallium were produced by heating for 6 to 12 hr. in hydrogen at 1110° F. Diffusion was improved by an intermediate coating of indium followed by the thallium, and finally indium again.

Amsler tests showed that thallium improved the seizure resistance of silver against a ground shaft but decreased it somewhat against a polished shaft. The 2% thallium alloy appeared to be the best. The homogenized alloys were somewhat more seizure resistant than cast alloys. A plated alloy with a 2% thallium surface showed results about the same as the equivalent cast alloy (final seizure load on ground shaft was 55 kg. for a cast 2.1% thallium alloy). For comparison, a 71% copper, 27% lead, 2% tin alloy showed a final seizure load of 36 kg.

A steel-backed, silver-thallium alloy with about 1.8% thallium passed the General Motors bearing test without any signs of distress. A comparative pure silver bearing was rather heavily filmed but otherwise in excellent condition.

It is believed that the difficulties experienced with pure silver bearings may be due to an erratic seizing tendency. Seizure was greatly decreased if there was sufficient sulphur in the lubricant to tarnish the silver. If this is correct, the corrodible silver-thallium alloys should perform better in service than pure silver bearings.



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